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PAGE 50

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JANUARY 2005


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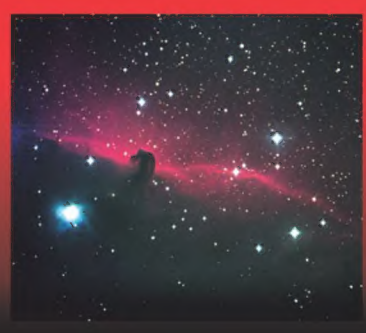

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DECEMBER 2004/JANUARY 2005 VOL. 19 NO. 5

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The vision thing.

bonus GLOBAL HAWK poster

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Admiral Ramsey's Room

Among the most intriguing and unusual assets of the National Air and Space Museum Library are the special collections, which are housed in the DeWitt Clinton Ramsey Room, located just off the library's main reading room.

The Museum's special collections comprise books, journals, and pamphlets, as well as manuscripts and sound recordings. Because of their rarity, cost, beauty, unusual content, or fragile condition, these works demand the best and most secure storage, and the Ramsey Room provides a safe, climate-controlled environment as well as good physical security.

Having just celebrated its 100th year, aviation is such a new field that people will wonder how there could be rare books and special collections devoted to it. But the history of flight reaches past the history of powered airplanes.

Ballooning experiments in both England and France led to flights in the 1780s. Research by scientists such as Robert Boyle and Joseph Priestly, who studied the physics of the air and worked out the composition and behavior of gases, enabled the Montgolfier brothers of France and other adventurous innovators to build balloons that rose into the air bearing humans. Examples of early ballooning texts in the collection include a description of the Vauxhall Royal Balloon in the *Scrapbook of Early Aeronautica* (England, 1783–1840) by William Upcott, a gift of Mrs. John Carruthers, and Barthelemy Faujas de Saint-Fond's *Description des Experiences de la Machine-Aerostatique de MM. de Montgolfier* (A Description of the Experiments of the Montgolfiers' Aerial Machine; Paris, 1783–1784).

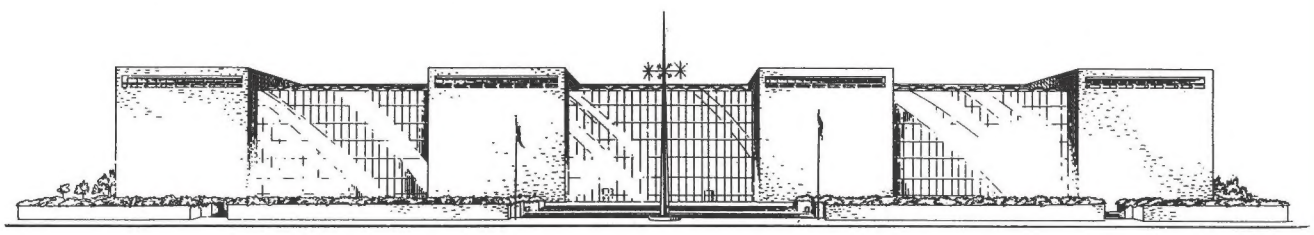
Rocketry dates back to the Chinese use of rockets in fireworks, mostly for entertainment, as long as a thousand years ago. Amedee Frezier described rockets used in 18th century celebrations in *Traite des Feux d'Artifice pour la Spectacle* (Treatise on Fireworks for Display), published in 1747 and now part of the Museum's special collections. The Ramsey Room also has speculative and theoretical works by Germans, such as Hermann Oberth's *Die Rakete zu den Planetraumen* (Rockets Into Planetary Space), published in 1923, and Otto Willi Gail's 1928 *Mit Raketendraft ins Weltenall: Vom Feurewagen zum Raumschiff* (With Rockets into Space: From Fire Engine to Spaceship).

Another treasure trove in the Ramsey Room is the Bella Landauer Collection of Aeronautical Sheet Music. The compilation's 800 titles vividly convey the public's continuing enthusiasm for manned flight.

The room is named for DeWitt Clinton Ramsey, a naval aviator who rose through the ranks to take command of the Pacific fleet in World War II. He was decorated by the United States and several other nations, and concluded his military career as commander-in-chief, Pacific fleet, and commander of the Trust Territory of the Pacific Islands.

Admiral Ramsey died in 1961, and his wife, Juanita, set up a memorial fund that established the Ramsey Room, as well as the Ramsey Fellowship, which is awarded annually by the Museum.

—J.R. Dailey is the director of the National Air and Space Museum.



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Air & Space/Smithsonian (ISSN 0886-2257) is published bimonthly by Smithsonian Business Ventures, MRC 951, P.O. Box 37012, Washington, DC 20013. Editorial offices: MRC 951, P.O. Box 37012, Washington, DC 20013. Circulation and advertising offices: 420 Lexington Ave., New York, NY 10170. Canadian publication agreement no. 40039324. Canadian return address: Station A, P.O. Box 54, Windsor, Ontario N9A 6J5.

Subscription Prices: U.S. and possessions: $24 a year payable in U.S. funds. Canada and all other countries: add $6.00 (U.S. funds) per year. Eighty-five percent of dues is designated for magazine subscription. Current issue price: $3.99 (U.S. funds). Back issue price: $7.00 (U.S. funds). Periodical postage paid at Washington, DC, and additional mailing offices.

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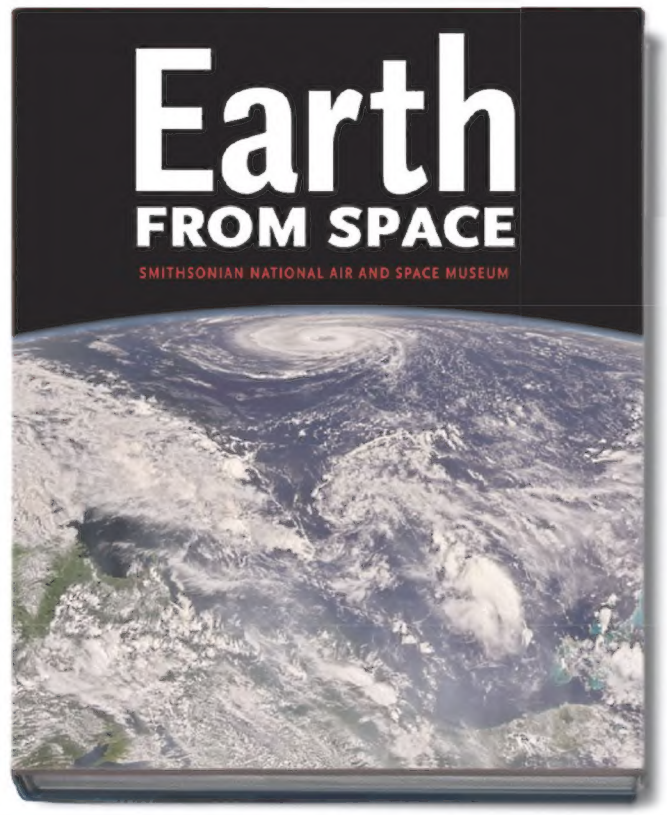

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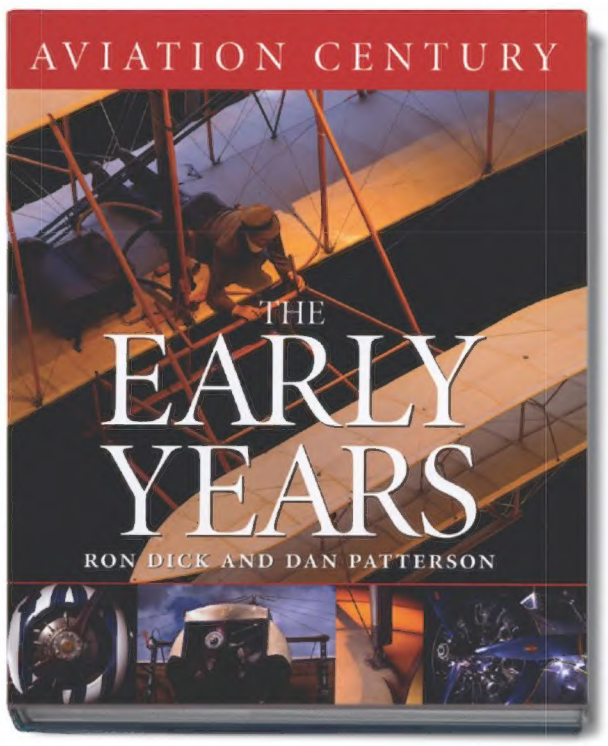

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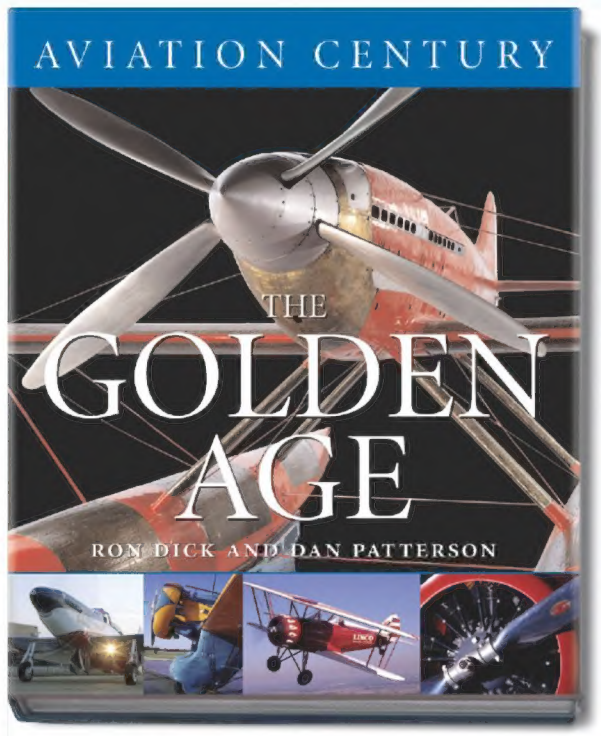

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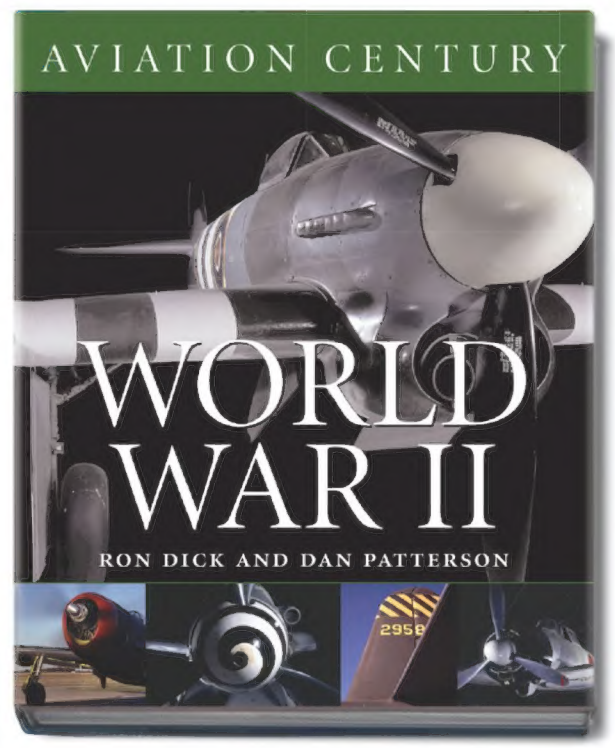

Begins with 1939-40, the German blitzkrieg and ends after the *Enola Gay's* war-ending flight.

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LETTERS

German Kamikazes?

"Crown Jewels" (Oct./Nov. 2004) refers to the German V-1 "buzz bomb"—the Fieseler Fi 103R Reichenberg—having a cockpit "from which the pilot was to jump after pointing the cruise missile at its target." I lived near the late Willy Fiedler, test director of the V-1 program, and in 1991 I talked with him about the piloted version. Mr. Fiedler told me that the idea for a piloted version was proposed directly to Adolf Hitler by Germany's first female flight captain and national hero, Hanna Reitsch. V-1s had a very crude guidance system and were known to be highly inaccurate. Reitsch recommended that pilots actually fly the missiles into key targets, kamikaze-style, thus ensuring direct hits. She believed that loyal, brave German men would volunteer for these sacrificial missions.

Mr. Fiedler claimed that Hitler wasn't enthusiastic about the idea, but did authorize the construction of a few V-1s with cockpits. Fiedler went on to say that only one V-1 was ever launched with a pilot, and it landed, not crashed, using a rigged landing gear. The program was discontinued because, said Fiedler, Hitler found the concept distasteful.

Documentary and Hollywood representations have Reitsch making that single V-1 flight, but Fiedler said it was actually he who made it, and he showed me photos that appeared to validate the claim.

After the war, Fiedler played an active role in the development of the U.S. cruise missile program. He seemed to be a fine man, and he expressed remorse for the damage his wartime products did to civilian populations.

John Gordon
Los Altos, California

New Zealand Buzz Bombers?

The photo at the bottom of page 72 in "The WoW Factor" (Aug./Sept. 2004) shows what looks like a Nazi buzz bomb on a launching ramp. Do you know if it was ever launched there in New Zealand?

George Pearce
Webster, New York

Editors' reply: We passed your question on to Ian Brodie, director of Wanaka's New Zealand Fighter Pilots Museum, and he told us that you are correct: At the bottom of the photo there is indeed a V-1 buzz bomb. However, it is only a wooden replica, and what makes it look like it is about to be launched is a pyrotechnics smoke apparatus.

Fading Clues

"The Mystery of the Lost Clipper" (Aug./Sept. 2004) may have cleared up a mystery for me. I was a young pilot aboard the aircraft carrier USS *Kearsarge* the day Pan American Airways Flight 7 crashed, and I heard nothing about it. We were isolated from all world events except for letters from home. At the time of the crash, we were in the Pacific but probably close to the Philippines. I remember receiving a letter from home that arrived weeks after it had been sent; the envelope had been torn and repaired, and the letter had obviously been immersed, as the ink looked smeared and faded, except for a note on the back of the envelope explaining that the letter had been retrieved from the water after an airliner crash at sea. Now I wonder if my letter had been on *Clipper Romance of the Skies*.

Charles Drewes
Garden Prairie, Illinois

Your article was well written and interesting, but the designer spoiled a bunch of good clippings, photographs, drawings, and a handwritten letter by fading them, just to make the article look mysterious and ghostly.

Lt. Col. Robert K. Scudder
U.S. Air Force (ret.)
Riverside, Calfornia

Primordial But Immortal

In response to the sidebar "The Primordial Model Jet Engine" ("Tiny Turbines," Aug./Sept. 2004), I wish to assure readers that the Dyna-Jet is alive and well, and has been copied numerous times, both in this country and overseas. As for any supposed difficulties in operating, the engines are usually simple to start when not doctored or "hopped up" in some radical way. The only time raw fuel "drizzles" out the exhaust is when it is mistreated. Further, the tailpipe does not need to warm up before the engine will start. I have witnessed a seven-foot-long version run satisfactorily during a thorough dousing of the tailpipe with cold water.

Gerald L. Wiles
Bradford, Ohio

We found our best watch in a history book

In 1922, a small watchmaker in Switzerland designed the first automatic watch to display the day, month and date. Only 7 of these magnificent timepieces were ever made and this watch was almost lost to history. Today, they are so rare that our watch historians are willing to bid $300,000 for an original in mint condition.

These watches were among the most stylish of the roaring 20's. The Stauer watch design that you see here has the antique color, the vintage style and the innovative functions of the original that we have seen in a Swiss museum. Even the Breguet™ style hands are designed from the original. The owner of this legendary multi-functional watch is sure to look distinguished and set apart from the crowd. This Stauer watch is a limited edition, allowing you to wear a watch far more exclusive than many luxury brands.

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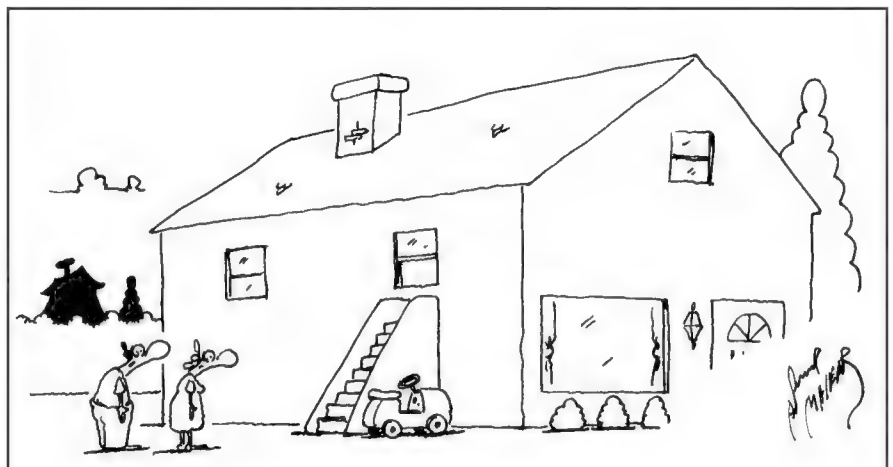
Champion of the Comet

Several years ago, I was most privileged to meet John Cunningham, the man who test flew the de Havilland Comet ("Celestial Body," Restoration, Dec. 2003/ Jan. 2004). To his dying day, Cunningham vigorously refuted claims that the Comet was an inherently dangerous aircraft. He flew various models of it, and declared them all "a joy to fly." Cunningham's faith in the airplane has since proved correct: The military version, the Nimrod, has been giving sterling service for years.

Roy Fordham
Cairns, North Queensland,
Australia



"It looks like our daughter eloped with that guy from the airport!"

A Few Undignified Moments for Howard Hughes

"Howard Hughes' Top Ten" (Oct./Nov. 2004) brought to mind a story I have never seen any reference to. It was late 1940, and in order to make money to continue my education, I had taken a job helping to build aircraft at Lockheed in Burbank, California. During lunch breaks, I, along with many other employees, would sit in the shade of a hangar near the head of the runway and watch planes taxi out and take off.

One sunny day we spotted one of Lockheed's new Model 12 twin-engine (and twin-tail) craft taxiing along the ramp. At the head of the runway, it swiveled around, and the pilot started preflighting it. We saw all the controls being exercised, and then the engines were revved and checked. The plane was ready for takeoff. The engines were set to full rpm, and I was expecting the brakes to be released and the plane to start rolling down the runway. But much to my and everyone else's surprise, the landing gear started to retract. The plane tilted forward and came crashing down to the ground. The props hit the pavement and bent, and the engines stopped; two columns of smoke started curling up from the nacelles.

All was quiet. Nothing moved, and no one spoke for a couple of minutes. Then the cabin door opened, and out stepped the tall, easily recognized figure of Howard Hughes, wearing one of his wide-brim hats. Obviously embarrassed as well as angry, he quickly stamped off.

Allan LeVantine
Palm Desert, California

One story about Howard Hughes' aviation experiences stems from his crash in the XF-11. Apparently, during his long recovery in the hospital, he needed to have his bed configuration constantly changed. Back then, the beds had hand cranks, and the nurses had to use them to make adjustments.

Realizing that this was a major part of a nurse's duties, Hughes called his chief of engineering and directed him to come up with a method that would allow the patient to adjust the bed himself. Almost overnight, Hughes Aircraft produced a powered bed much like those used in hospitals today.

Roy Benstead
El Cajon, California

Mourning Electra

I was part of the crew that helped transport the airframe of Lockheed Electra serial no. 1052 to the New England Air Museum ("Northwest Passage," Restoration, Aug./Sept. 2004). The Electra was being kept in the storage space of a Pratt & Whitney employee [who in two days would have become owner of the aircraft by default], and he was not happy we showed up. But we had only a short time to get the load ready, and were more concerned about the safety of the crowds watching us than anyone's sentimental feelings about the aircraft. Later, the employee's daughter told us about her father's attachment to the Electra, and I started to feel like a heartless repo man (which wasn't an entirely untrue characterization).

Staff Sgt. Roderick M. Bertrand
Florida Army National Guard
Bunnell, Florida

Flabob: Flop?

After reading "The People and Planes of Flabob" (Oct./Nov. 2004), we were eager to visit it. We drove some 70 miles from our home, but when we arrived at Flabob, the hangars were closed and locked, and there were fewer than 10 aircraft on the ground, all common types. We were very disappointed. The only positive was that we were able to use the airport's restroom before driving home.

Arlene and Paul Stiglic
Torrance, California

Corrections

Oct./Nov. 2004 "The First Shuttle" (In the Museum): An incorrect impression was given by the phrase "The four people who did the work also refurbished the *Enola Gay*...." The restoration of that aircraft involved more than 100 people.

"Contact": The Curtiss Seagull was a flying boat; it did not have pontoons. The error was introduced during editing.

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All letters selected for publication are edited. We regret that we cannot respond to every letter.

The Next Action Figure?

When Yves Rossy stepped out of an airplane above the Swiss Alps last June, you can bet he was thinking "Bond. James Bond."

Rossy, a Swiss International Air Lines pilot and avid skydiver, had strapped to his back a folded 10-foot-long carbon-fiber wing he'd built, with a tiny jet engine installed on either tip. After locking the wing down into position, "I went in a [descending] glide flight for about a minute at about 3,000 meters [nearly 10,000 feet]," he says. "I started the engines in the glide and it took 30 seconds until they are stabilized, and I give more power." Once he'd achieved level flight, he killed the jets, folded the wingtips, and descended by parachute.

That was actually the jet wing's 26th flight; Rossy had made 25 unpowered glides to make sure the wing was stable. So far, he's made five additional powered flights. Top speed: 112 mph; longest level flight, four minutes. "My goal is to go until the end of fuel," he says. "I have fuel for 10 minutes."

The wing is simple and easy to control. "I can move the wing up and down on my back," Rossy explains. "I can choose if I want to go down or up with the displacement of the center of gravity. I have also electrical aileron controls, to help especially to come back to wings-level. My goal is to fly this without anything other than with my body."

This is just the first prototype, Rossy points out. He's building another wing that's lighter (the first weighs between 70 and 75 pounds—"too heavy," he says), and more refined (it will be aerobatic). "My goal is to climb. As soon as I can climb, I can take off from a car or a motorboat from the ground." And that will lead him to Hollywood: He says his wing is perfect for a supporting role in action-adventure movies. "I would be very happy to participate in a James Bond movie," he says. "That is my goal. It is very good for the ego."

—Phil Scott

PASCAL MIGNOT/KEYSTONE

Yves Rossy channels James Bond as he soars over the Alps on his twin-jet homebuilt carbon fiber wing.

Lightweights

Buzz Aldrin jumps, jigs, and somersaults in microgravity on a parabolic flight high above the Pacific Ocean, off the coast of southern California. This is the first time he's been able to bound in microgravity since Apollo 11 in 1969, and I and 25 other people plus a crew of nine, have the good fortune of sharing the occasion. We're on G Force One for its debut flight from Los Angeles. Now anyone who's got the $2,900 to pay for a ticket can "go zero." "It's a stepping stone to the objective that so many people have: to experience spaceflight," Aldrin says.

The brainchild of Peter Diamandis — creator of the Ansari X Prize—and former space shuttle astronaut and airline pilot Byron Lichtenberg, Zero Gravity Corp. is the first private operator approved by the Federal Aviation Administration to offer civilians the same kind of parabolic flights on which astronauts train for the sustained microgravity of space. The idea emerged a little more than a decade ago, during some downtime at a space conference. Following his "mediocre success" with International MicroSpace, a commercial small-satellite rocket business that launched into a "dismal marketplace," Diamandis concluded that "self-loading carbon payloads—people—are the only real market. They come with their own money and there are lots of them, and 60 percent of the public says they would like a chance to travel in space." In 1995, Diamandis and Lichtenberg began raising money to start an airline offering weightless flights.

They chose a Boeing 727 because "it's the same size [cabin cross-section] as NASA's KC-135 and it has centerline thrust, and is a very strong, high-Mach-

number airplane," Diamandis says. The entrepreneurs added accelerometers in the cockpit so the crew could monitor the G-loading and upgraded the hydraulic system to sustain hydraulic pressure during the performance of parabolic arcs, a modification for which they received a patent.

"The other thing I realized is that a lot of cargo freighters flew during the week but not on weekends, and we considered this initially as a weekend business," Diamandis says. So Zero G would use airplanes that hauled cargo during the week. By 2000, the two men had modified their first 727 and with Hamilton Aviation conducted flight tests in Tucson, Arizona.

Then they tackled getting approval from the FAA, which took nearly eight years. "It was very difficult for them from a legal standpoint to figure out how to classify this," Diamandis says. "Were we a Part 91 operation [non-commercial] or Part 125 operation [medium aircraft seating 10 to 30]—what were we?"

Finally, in August 2002, FAA headquarters advised the company "that we should and could operate this under Part 121 of the regulations [large aircraft with over 30 seats]," says Diamandis.

Within weeks, Amerijet International, a global cargo company, signed on. While Amerijet owns the jets, Zero G owns the patents, pays for modifying the jets, and has the exclusive right to use the modified aircraft. The FAA tested and approved the modifications with Supplemental Type Certificates, all of which Zero G owns.

JIM CAMPBELL/AERO-NEWS NETWORK

Apollo 11's Buzz Aldrin, second from right, is tickled to be back in microgravity—and able to share it.

Still, there were obstacles. Under Part 121, anyone on an aircraft that reaches a nose-up or nose-down attitude of 30 degrees or more relative to the horizon has to wear a parachute, and Zero G's aircraft would be flying up to 50-degree nose-up and -down attitudes for the parabolas. (At 15 parabolas per flight, customers log a total of about eight minutes of various degrees of microgravity.) "But the airplane is always controlled, and it's flying an instrument maneuver, so you don't really need to wear a parachute," says Diamandis. Zero G and Amerijet filed for that and other exemptions, and following inspection and validation flights, got FAA approval.

Although both Zero G and Amerijet are based in Fort Lauderdale, Florida, as business expands, the aircraft will travel. Eventually, the company may open an operation in Las Vegas to service the West Coast. Zero G has enlisted partners overseas to offer weightless flights to civilians in Russia on an Ilyushin Il-76, and in Europe on an Airbus 300.

"Tourism in space is no longer the giggle it was 10 years ago," says Aldrin. "Since being on the moon, I have wanted to see exploration continue, but without the enthusiastic support of the general public, it just isn't going to happen. This is the beginning. I can't think of anything better right now, unless it's going to the moon."

—A.J.S. Rayl

PHZ (AW/SW) MARLOWE DIX

The Best Jobs in Aerospace

Lieutenant Commander
Matthew "Potzo" Pothier

Officer in Charge, U.S. Navy
Landing Signal Officer School

Naval Air Station Oceana,
Virginia Beach, Virginia

Landing a jet on a carrier is tough, especially at night. Pilots aim for one of four wires strung across the middle of the deck. If the jet is on target, its arresting hook catches a wire and it decelerates from 155 mph to 0 mph in 170 feet. If the jet is too high, it misses all the wires and goes around for another try. If it's too low, we "wave them off" to try again. If the airplane is outside a theoretical two-foot target window, it will either be too high and miss, or worse, too low and crash.

This is the only school of its kind. We instruct all qualification levels of landing signal officers, even foreign ones. One of the most significant courses in our curriculum is the safety seminar, where we Monday-morning-quarterback videos of fiery crashes and mishaps. Our students finally realize that the lives of fellow aviators are in their hands.

LSOs must be proficient pilots in order to have credibility with the pilots they are waving. As the head LSO (I hold one of the four senior LSO positions in the Navy), my job is making sure each jet comes back safely, training junior LSOs, and instructing the pilots in the air wing to work around an aircraft carrier safely.

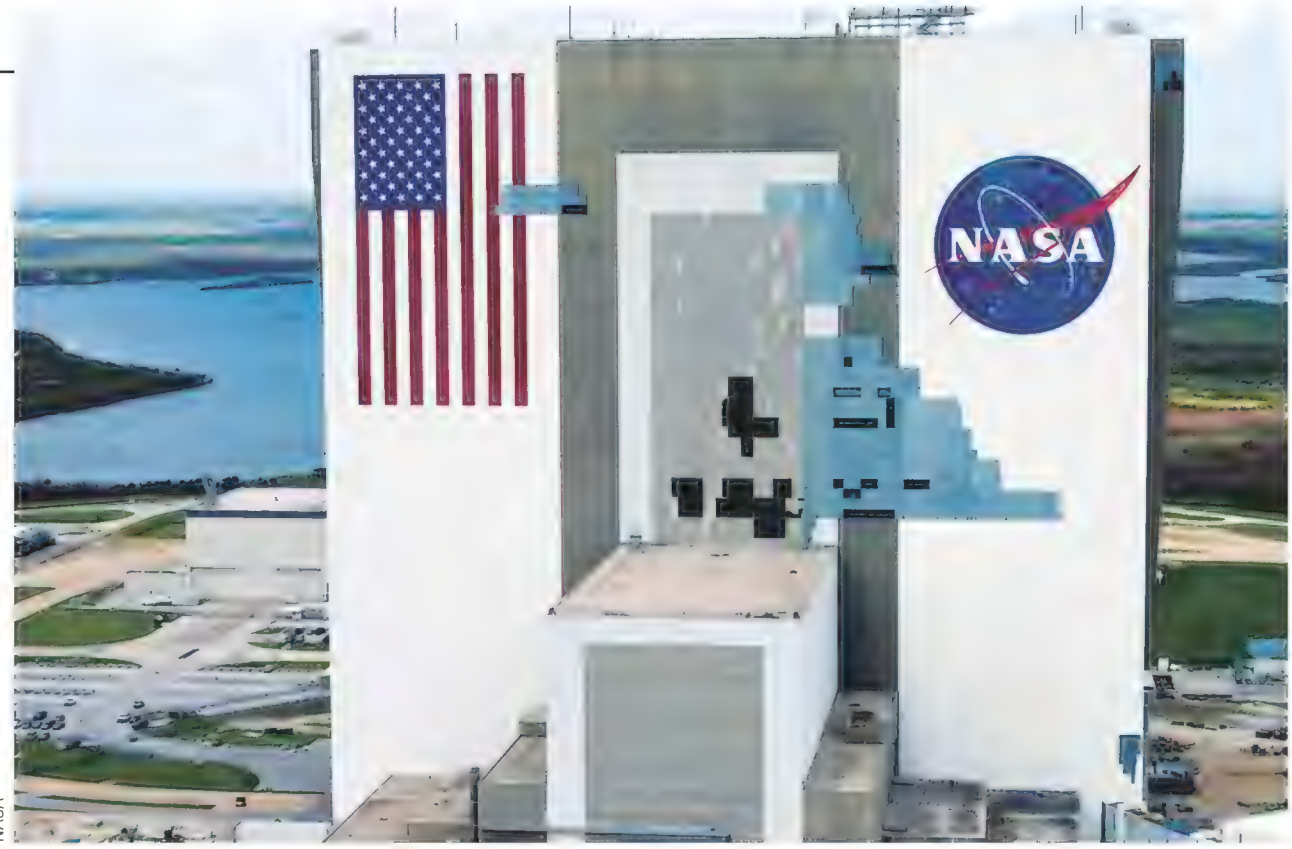
The best part about the military is that they let me fly a $40 million high-performance fighter jet all by myself. I get to rip around through the sky with this nimble beast at my command. I still feel like a little kid whenever I launch into the boundless blue sky. This is what keeps us coming back for more, despite the spartan environment of a Navy ship at sea.

I am about to deploy again as a department head on the USS *John F. Kennedy.* Unfortunately, there are no more jobs for me as an LSO—I am too senior, and have to hang up my paddles.

Space Center Takes Licking, Keeps on Ticking

If solving life-threatening technical problems, wrangling money from Congress, and oiling the wheels of bureaucracy were not enough, NASA faces a new obstacle in its nearly two-year quest to return the shuttle fleet to flight. Last summer, an unprecedented three hurricanes clipped the Kennedy Space Center in Florida, causing millions of dollars in damage and adding as much as four months of work before the first post-*Columbia* shuttle mission lifts off. NASA had been targeting its return-to-flight mission for next March or April.

Hurricane Charley, which blasted through central Florida from the west, was the warmup act, arriving mid-August, just at the peak of hurricane season. Only the northernmost corner of the space center was affected, but damages tallied between $750,000 and $1 million, says Jim Kennedy, who heads the Florida spaceport.



NASA

The Vehicle Assembly Building got hammered by hurricanes.

Three weeks later, Frances came ashore south of the Kennedy center, but packing powerful enough winds to poke holes in the massive Vehicle Assembly Building, as well as pry the roof off a shuttle tile manufacturing facility.

Even so, director Kennedy was quick to count his blessings. While the damage was the worst ever seen at the spaceport, it was not a disaster, he said in a teleconference with reporters. "I don't want to speculate on what possible worse damage we could have with a category 2, 3, 4, 5 direct hit," he added.

Frances' sustained winds of more than 70 mph ripped 820 four- by 16-foot siding panels from the VAB, leaving many sections completely open to the elements. "When you're inside the VAB, you can see sky," said Kennedy.

The shuttle tile manufacturing equipment was relocated to a state-owned hangar originally built for the Reusable Launch Vehicle program and more recently used by investigators to piece together the debris of *Columbia*.

The center went into full alert for the next storm, Hurricane Ivan, but Ivan's turn away from Florida's east coast bought NASA just a bit more time. Hurricane Jeanne, smaller but more powerful than Frances, was on the way less than two weeks later.

Jeanne, which made landfall only two miles from where Frances came ashore, traveled farther west, much to the relief of NASA. The storm claimed another 25 panels from the VAB and soaked the Operations and Checkout Building, which had roof damage.

The shuttles rode out the storms in the Orbiter Processing Facility. Their payload bay doors were closed and their wheels raised off the floor in case of flooding. They escaped the storms without damage, as did the billions of dollars' worth of space station gear awaiting transport to orbit.

NASA hired local contractors to work around the clock, hoping to patch the VAB with panels of corrugated steel before more storms arrived. Eventually, the entire VAB roof is scheduled to be replaced at a cost of $10 million, an upgrade that was on the books well before the hurricanes struck.

—Irene Mona Klotz

That Darn Dihedral Effect

The second X Prize flight of SpaceShipOne last October unfolded perfectly—so perfectly, in fact, that as the rocket plane coasted toward apogee, its tail camera captured Venus, perfectly stationary, below the opposite fin and boom.

But it was the heart-stopping sight on the flight five days earlier, during which the spaceplane seemed to spin out of control atop a slender pillar of smoke, that is burned in the public's memory. As it blasted upward at three times the speed of sound, SpaceShipOne rolled 29 times.

Inside SpaceShipOne, the imperturbable Mike Melvill, who had piloted the craft through several previous crises, put his hand over the motor cutoff switch, fixed his eyes on his instruments, and ignored the spinning world outside. He patiently brought the spaceplane under control, and later threw in an additional roll just for fun as he glided back to land. But everyone wondered how an aircraft capable of such antics would be able to fly again in just a few days.

It did, of course. Within 24 hours of

So, What's NXT?

Jon Sharp's 400-mph Sport Class racer, NemesisNXT, set to make its debut at the Reno Air Races last September ("Air Racing News," Soundings, Aug./Sept. 2004), was grounded by a collapse of the landing gear when the airplane landed at Reno's Stead Airport and skidded off the runway. Sharp attributed the kitplane's gear collapse to "a purchased part in the landing gear system subjected to a condition it was not supposed to be in." The left wingtip and belly were badly scraped and the propeller was bent, but NemesisNXT was flown home to Mojave, California, after Lycoming installed a new engine. Meanwhile, Lycoming is checking the original for damage from the propeller strike.

JIM KOEPNICK/EAA

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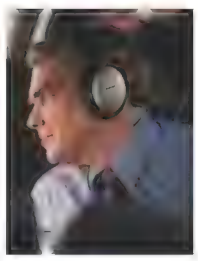

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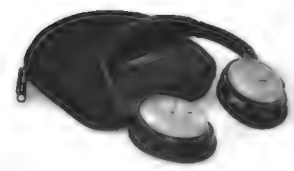

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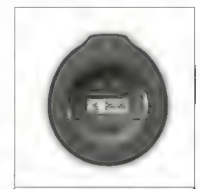

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the flight, designer Burt Rutan had publicly explained everything about the rolls except the somewhat abstruse initial cause, which he said he'd get to later. The important thing to understand, he said, was that SpaceShipOne had continued to roll simply because the initial departure from controlled flight occurred near the edge of the atmosphere, where there was not enough air to allow the normal flight controls to work. Not quite enough: Actually, Melvill had already brought the roll rate down from 180 degrees a second to about 140 by the time the spaceplane—now weightless, in a vacuum, and jackknifed into its "feather" configuration for reentry—could be stabilized by a couple of long blasts of its wingtip thrusters.

The cause of the rolls was found in a seemingly innocuous control input. Climbing vertically along a perfect trajectory at almost Mach 3, Melvill had pushed the stick forward to keep the spaceship from pitching past vertical. The resulting slight negative G revealed a directional instability in the design, one that exists only around Mach 3 and with the stick forward. The instability magnified a routine rudder movement, allowing the ship's nose to swing several degrees to one side. This in itself might not have been a problem if SpaceShipOne did not suffer from an extreme excess of what aerodynamicists call dihedral effect, which means that it reacts to swings of the nose with a powerful tendency to roll. What had started the rolling, therefore, was actually a small forward stick movement near Mach 3; what kept it from stopping was the absence of air.

Once this was known, the project's engineers reprogrammed the flight trajectory, along which the pilot is guided by the so-called TONU, or Tier One navigation unit, to ensure that the pilot is always pulling positive G during the climb. It was adherence to this new trajectory that allowed pilot Brian Binnie to achieve a flawless flight.

As for Melvill—"Well," he said, "I think I'll try to get into the Guinness Book with the longest series of vertical rolls ever performed at Mach 3."

—Peter Garrison

WORK IN PROGRESS

BILL DUNBAR

After 56 years under water and six more on the run, the world's only Brewster fighter came back to the U.S. Navy last August. Allied pilots considered the Buffalo a slug, but the Finns used the roly-poly fighter, which they named "Sky Pearl," to great effect against the Russians. Shot down in June 1942, BW-372 was pulled from a lake in the Karelyia region, near the Finnish border, by a team of Russians, Finns, and Americans in 1998. (The tires, manufactured by Finland's Nokia, were still fully inflated.) Seized by the Russian government, the Buffalo was then acquired by a series of shadowy companies that left its ownership a conundrum. In the end, the Navy swapped three surplus Lockheed P-3 Orion patrol aircraft for it. Its last owner of record, Vintage Holdings, got the P-3s. The Museum of Naval Aviation in Pensacola, Florida, will reassemble the aircraft (it was cut in half for transport) and display it in its Finnish air force livery, including the *hakaristi* that many people will take for a Nazi swastika. In fact, the bent-leg cross was a good-luck symbol used by many cultures.

Picking up the Pieces

Last October, the Genesis Mission's solar wind collectors returned to the Johnson Space Center in Houston on a NASA jet, handled as high-value cargo. Genesis was salvaged by Johnson's curatorial team, the scientists and technicians who preserve moon rocks and other extraterrestrial material.

Genesis' silicon, diamond, gold, and germanium collectors had been assembled in Johnson's Class 10 clean room, which, measured by airborne particle counts, is 1,000 times cleaner than hospital operating rooms. To keep the collectors from being contaminated by atoms other than those from the solar wind, curators cleaned thousands of components, including screws for installing collector wafers in five gleaming arrays. After a journey to the sun-Earth libration point, L-1, Genesis spent 27 months exposing its collectors to the solar wind.

When Genesis returned, the curatorial team was in Utah to support and document the recovery work done by teams from Lockheed Martin Aerospace and the Jet Propulsion Laboratory. Genesis curator Karen McNamara had devised contingency plans for disaster, including field recovery kits—buckets packed with garden trowels, cat litter scoops, tweezers, pocket notebooks, ballpoint pens, permanent markers, and thousands of laboriously pre-numbered Ziploc bags.

The Genesis capsule fell in the correct trajectory toward the Utah Test and Training Range. Two Eurocopter AStar helicopters took off to snag the capsule's parachute mid-air and lower it to Earth (see "Helluva Catch," Aug./Sept. 2004), but the drogue and main parachute didn't open. Moments after Genesis slammed into soft, salty ground, Lockheed Martin's recovery team members grabbed the field recovery buckets on their way to the crash site. McNamara began retrieval of the broken capsule in the field.

In a temporary clean room at the U.S. Army Proving Ground in Dugway, Utah, Genesis scientists and Johnson curators spent four weeks of 12-hour days preparing damaged sample collectors for safe transportation. "It was heart-wrenching," says Eileen Stansbery, Genesis contamination control lead scientist and a JSC curator herself. "We knew we had solar wind, but we'd have so much work to do." The mirror-bright arrays had shattered. However, the most important collectors, a gold foil and four oxygen concentrator targets, were extricated from the wreckage mostly intact. The salvage work the curators did has made researchers optimistic that the traces of the sun that Genesis caught at L-1 will reveal the primordial composition of our solar system.

—Alexis Glynn Latner

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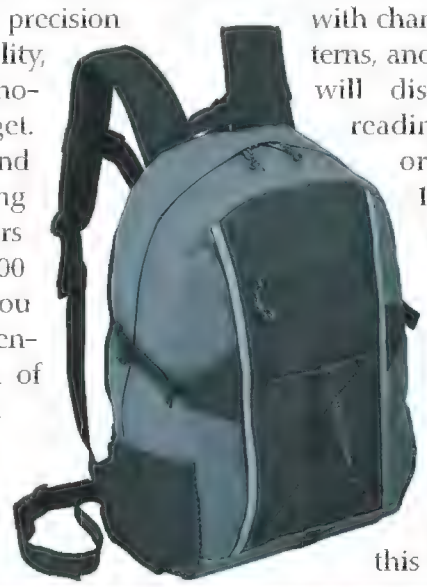

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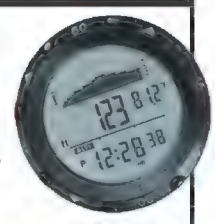

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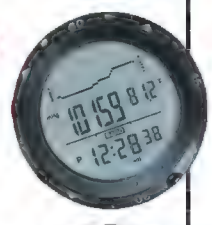

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Hot off the Test Range

After serving as a fighter pilot and T-38 instructor pilot for the U.S. Air Force, I became the curator for the National Air and Space Museum's modern military aircraft collection in June 2001, just about the time that the Lockheed Martin X-35B was setting records in the California desert.

Five months later, I learned that the X-35B might be available for our collection. The Joint Strike Fighter program, which was testing three variants of a fighter design for the Air Force, the Navy, and the Marine Corps, was closing down, and the program's directors were seeking permanent homes for the test aircraft at museums and military bases.

Normally, the Museum does not make a high priority of collecting technology demonstration aircraft (many of them never become operational or they fail to achieve program objectives). But there are several experimental aircraft that we have acquired. The Bell X-1 *Glamorous Glennis*, for example, became the first aircraft to fly faster than the speed of sound on October 14, 1947. The North American X-15 rocket-propelled aircraft reached Mach 6 and flew at an altitude of more than 100,000 feet. And the Bell XP-59 was the United States' first jet airplane.

The X-35B too is remarkable, and we thus decided to acquire it for our collection. A painting on the aircraft's tail, three ace cards popping out of a top hat, signifies the three types of landings that the Joint Strike Fighter program accomplished: conventional, carrier, and vertical. The X-35B had started out as the X-35A, a conventional-takeoff-and-landing airframe designed for the Air Force. After a successful test program, the X-35A was equipped with a shaft-driven lift fan propulsion system in January 2001, and redesignated the X-35B (see "Winner Take All," Dec. 2002/Jan. 2003).

Flight testing of the new propulsion system (the engine by Pratt & Whitney and the lift fan by Rolls-Royce) would explore the X-35B's short-takeoff-and-vertical-landing capability, which the Marine Corps required for its Joint Strike Fighter variant. Like a hockey player scoring three goals in one game, Marine Major Art Tomassetti scored his own "hat trick" on July 20, 2001, taking the X-35B through three flight modes on a single sortie: a short takeoff, a level supersonic run, and a vertical landing. On August 6, the X-35B made its last flight. Later that year, the designers of the X-35B's propulsion system were awarded the Collier Trophy for aeronautical achievement.

The aircraft was ready for retirement, but first it had to travel from Edwards Air Force Base in California to the Museum's Steven F. Udvar-Hazy Center in northern Virginia. Since the X-35B had been grounded after the flight test programs were complete and was no longer airworthy, it could not be flown across the country. And the X-35B's wing is a single structure that is inseparable from the rest of the airframe. It can't be unbolted, so the jet could not be disassembled for transport by a U.S. Air Force C-5 or C-17. And in its flight configuration, it was too wide to travel by road. The X-35B was

DANE PENLAND (2)

After wrapping up a flight test career in California, the X-35B traveled across the country on a flat-bed trailer (left). The jet is now a museum artifact on display at the Steven F. Udvar-Hazy Center in northern Virginia (above). Mechanics later reattached the X-35B's wing, which was removed for the road trip.

going to have to be "de-engineered."

Enter Worldwide Aircraft Recovery, an Omaha, Nebraska group of mechanics. They happened to be moving another aircraft at Edwards, and they had time to inspect the X-35B and develop a plan for moving it.

With help from the X-35's design team, the folks from Worldwide identified the wing spar location and developed plans to remove the right and left sides of the wing where they joined the fuselage. After removing structural wing panels, the crew cut through the alternating titanium and aluminum wing supports, always considering the detachment locations that would best ease reattachment of the wing later. After removing the flaps and horizontal stabilator, the team loaded the X-35B and its wing sections onto a low-riding flat-bed tractor trailer and in mid-September 2003 began the 3,000-mile drive.

As the truck and its cargo passed through small Midwestern towns, they often drew enthusiastic crowds. On a few occasions, the X-35 made the local paper or the evening news. On Friday, September 26, 2003, the jet arrived at the Udvar-Hazy Center. There was no fanfare; the Center was to open December 15 as part of the Centennial of Flight celebration, and aircraft and artifacts were arriving almost hourly.

The Worldwide Aircraft Recovery team consisted of Marty Batura, Jim Hale, Roger Griffith, Bill Lemieux, and Donna Morris. I volunteered to act as "gofer boy," and ended up as an apprentice mechanic, helping to reattach the top wing panels and flap and aileron covers; the job took more fasteners than I could count. Before the trip east, Batura's team had removed thousands of screw-like fasteners from the X-35's wing and pressed them one by one into a piece of Styrofoam that had been cut into the exact shape of the wing. I'll be happy if I never see another X-35 wing fastener—ever.

We worked for the rest of the day Friday and all day Saturday and Sunday, assembling the aircraft from pitot tube to trailing edge. The wing splices that Worldwide had fabricated were a perfect fit, and we reattached the wings in no time; then we started on the leading and trailing edges. By Monday morning we were done—not bad, considering three men working with a forklift and ladder were attempting something previously accomplished only in a factory.

The reassembly went so quickly in part because we had no propulsion system to install. One of the frustrations of collecting technology demonstrators is that sometimes the technology is still being demonstrated; so it is with the X-35B lift fan. Soon, however, the award-winning propulsion system will make its way to the Udvar-Hazy Center, where it will be displayed near the aircraft so that visitors may marvel at the technology that lifts a jet vertically off the earth and sends it hurtling through the skies faster than the speed of sound.

—Dik Daso

ARTIFACTS

ERIC LONG

In 1935 George Putnam commissioned a teak chest from Albert Wood and Five Sons of Port Washington, New York, as a Christmas gift to his wife, Amelia Earhart. Putnam wanted his wife to have the chest to store the trophies and awards she had earned during her flying career. The chest features hand-carved designs noting Earhart's 1932 north Atlantic, 1935 Pacific, and 1935 Mexico solo flights. After the chest was completed in early December, it was put on display at the Arden Gallery in New York City, where Putnam took his wife on December 22 to surprise her with the gift. Earhart's mother received the chest after her daughter's disappearance in 1937; then the chest went to Earhart's sister, Muriel Earhart Morrissey, and finally to Morrissey's daughter, Amy M. Kleppner, who donated it to the National Air and Space Museum in 2003.

VISITOR INFORMATION

Location The National Air and Space Museum is located on the National Mall, along Independence Avenue SW, between 4th and 7th Streets, Washington, D.C. The Steven F. Udvar-Hazy Center is at 14390 Air and Space Museum Parkway, Chantilly, Virginia, near Washington-Dulles International Airport.

Hours The Museum on the Mall and the Udvar-Hazy Center are open from 10 a.m. to 5:30 p.m. every day except December 25.

Food The Museum on the Mall has the Wright Place Food Court, which offers selections from the breakfast and lunch menus of McDonald's, Boston Market, and Donatos Pizzeria. The Udvar-Hazy Center offers food service from Subway, located at the south end of the main hangar. A food court is scheduled to open next spring.

Donald D. Engen Tower The Udvar-Hazy Center has an observation tower from which visitors can watch air traffic arriving at and departing Washington-Dulles International Airport. The only way to access the tower is via an elevator that rises 164 feet above the ground. The elevator can transport 15 people every five minutes.

NASM Express Shuttle Bus A round-trip shuttle runs between the Museum and the Udvar-Hazy Center from 9 a.m. to 5 p.m. Since the $7 shuttle tickets sell out quickly, visitors are encouraged to purchase them in advance by calling (202) 633-4629.

December 3 The new IMAX film, *Fighter Pilot: Operation Red Flag*, opens at the Museum's Steven F. Udvar-Hazy Center in northern Virginia. Follow U.S. Air Force fighter pilot John Stratton as he progresses through a series of training exercises (see "Uncommon Force," p. 36). For a listing of showtimes and ticket prices, call (202) 633-4629 or visit *www.si.edu/imax*.

December 11 First Anniversary Celebration of the opening of the Steven F. Udvar-Hazy Center. This day-long celebration offers visitors a variety of hands-on activities, contests, giveaways, entertainment by local high school music ensembles, and discounts on items sold in the Udvar-Hazy Center store. 10 a.m. to 3 p.m. For complete details, visit *www.nasm.si.edu*.

The Long Road Home

In late July 1945, heavy hail hit the flying field outside Cambrai, France. I learned a lot from that storm—for instance, that the ailerons, horizontal stabilizers, and trim tabs on an A-26 Douglas Invader were covered with fabric, not metal, and hailstones can punch holes in them.

Each A-26 at the field was assigned a crew chief—a master sergeant—to keep it in shape. On the day after the hailstorm, my master sergeant and I sat on the wing of our A-26, number 376 Uncle, sewing patches of fabric over holes in an aileron. We had big needles, fabric, shears, a pot of glue, and a brush. Like every officer, from second lieutenant to general, I was in awe of master sergeants. Any commissioned rank could be achieved by freak of circumstance, but no one made master sergeant by accident.

After we had patched every hole and painted the patches with glue, the sergeant said, "We might as well run the engines up, long as we're here." I started the engines, warmed them up, and checked for a drop in engine rpm when running on one magneto, an ignition device. The right engine was fine, but the left engine showed a drop of 200 rpm.

"Hell," the sergeant said. "Needs plugs."

We drove a jeep to the maintenance shed and picked up 36 spark plugs and a pot of grease. I leaned back against the clamshell canopy and watched the master sergeant remove the cowling from the left engine and replace all the plugs. He showed me what he was doing at every step, particularly how he checked the gap between each plug's electrodes, then dabbed the plug with grease before screwing it into place.

The second thing I learned from the hailstorm was how to change the spark plugs in a Pratt & Whitney R-2800.

At the time of the hailstorm, we had been sitting around for three weeks, waiting for orders to fly back to the States. When the war in Europe ended in May, pilots with more than 50 missions went home, while those of us with less than 50 stayed in Europe, practicing low-altitude bombing and low-level formation flying, both of which might be useful when we were sent to the Pacific theater.

A couple of weeks after the hailstorm, orders came through: We were leaving for the States the next day. When I got out to the air field that afternoon, every other A-26 seemed to have a crew chief making last-minute checks, but not 376 Uncle. I climbed in, started the engines, and warmed them up, worrying about my master sergeant.

The left engine, with the new plugs, was fine—no mag drop. But the right engine showed a drop of more than 200 rpm. I cut the engines and sat there, looking around for a jeep coming with a master sergeant.

Would you trust yourself to change the spark plugs on a 2,000-horsepower engine that you're counting on to take you 3,000 miles across the north Atlantic? One does illogical things at age 22. I borrowed a jeep, drove to Maintenance, and got 36 spark plugs, a Phillips head screwdriver, a wrench, and a pot of grease.

> I could fly back to where I'd come from, at least until I was sure I was over land, and bail out. I knew the A-26 was a valuable airplane, but I had the notion that I was valuable too, even if my handling of generators was flawed.

I was pleased that I could get the cowling off with the screwdriver. From there, it was not too bad. I remembered how to gap the plugs, apply a dab of grease, and screw them into place. As I worked, A-26s were taxiing by me on their way out. Guys I knew waved, as if saying goodbye. The last of them had been gone an hour by the time I got the cowling back on. You know how sometimes, when you're trying to leave on a trip, last-minute chores seem to take longer than they should but you believe that things will go smoother if you can just leave? This was one of those times.

As I drove to the flightline to return the tools and check out at Operations, I noticed that the sky had clouded over. At Operations, a sergeant told me that because I was no longer considered part of the flight that had left earlier, I would have to file a flight plan. "Weather's getting thick over that way," he said. "You got a green card?"

A green card certified that you'd flown a specified number of hours in real instrument conditions. Of course I had no green card. It was rare for a combat pilot to log any flying time in bad weather. I told him I'd left my green card in my other pants.

"Well," he said, with a shrug. "Go ahead." After all, what was he going to do with an orphaned A-26?

I don't recall why, but we were supposed to turn the generator off before takeoff. I remembered to do that, but what I did not remember to do was turn the generator on later.

By the time I reached the English Channel, bad weather had set in, and I was flying mostly on instruments. Once in a while, through a break in the clouds, I'd get a glimpse of the channel, but right away I was in the soup again. After a while, off to the right, I saw a vast, dim glow: London, buried in heavy fog.

I took up a heading for Holyhead, Wales, and started to climb. I'd seen on the map that mountains in Wales went up to 8,000 feet. I leveled off at 10,000 and cranked in the Holyhead field frequency to fly by radio compass the rest of the way.

The radio was dead. It was then that I remembered the generator. In a flat-out panic, I turned it on, with no idea how long it would take to bring the radio back. I leaned the fuel mixture, checked my airspeed and heading, and refigured my estimated time of arrival. The panic subsided somewhat. Without a radio I couldn't call Mayday, but what the hell. If I got to the neighborhood of Holyhead according to my ETA, and still had no radio, and let down and found fog, I could climb back to 10,000 feet, make a 180-degree turn, fly back to where I'd come from, at least until I was sure I was over land, and bail out. I knew the A-26 was a valuable airplane, but at that moment I had the notion I was valuable too, even if my handling of generators was flawed.

I climbed to 12,000 feet and kept my heading and airspeed. From time to time, I tried the radio. Nothing.

At three minutes past my ETA for Holyhead, I let down. The radio started to crackle with static. I broke out of the clouds at 2,000 feet, directly over the shoreline. Holyhead lay in an unmistakable shape of coastline, not five miles north of where I'd let down. And the radio had come back, faintly. I could see the field, and called the tower. I got a barely audible response: Cleared to land.

Between midnight and two that morning, a loudspeaker in the barracks woke us with Bing Crosby singing "Happy Holiday." When the music stopped, a drunken voice said, "Japan has just surrendered."

In the bunk above me was Al Ainsley, my tentmate and roommate for the past six months. "So the war's over," he said. "I'm not flying any A-26 over all that cold water. I'm taking a boat home." From the responses around us, it seemed that Ainsley was speaking for everyone. But by morning, everyone wanted to fly home.

The flight to Keflavik, Iceland, went fine. But not long after we landed there, we were grounded. Air Transport Command decided the A-26 did not have the range to cross the north Atlantic. If we got close to Greenland and the field there was socked in, we wouldn't have enough fuel to get back to Iceland.

For days, those of the gambling persuasion played poker and shot craps around the clock. Those of the drinking persuasion tried to scrounge up booze. I went fishing from the cliffs with about 20 guys on an expedition led by a redheaded Red Cross girl. We caught three fish about the size of white perch. Nobody got near the redhead.

After five days, ATC relented. We could take the A-26s the rest of the way home. On the night before takeoff for Greenland, an intelligence officer showed us a film. "It's kind of a horror movie," he said, laughing. He had a keen sense of humor, like a lot of ground officers.

PAUL SALMON

We learned what to do if the weather turned bad and we couldn't fly a direct route over the ice cap to Bluie West One, a U.S. Army air base in southern Greenland. You hung a left when you got to the coast, flew for 20 minutes to the mouth of a fjord, took a right, then the first fjord on the left, and a right at another fjord marked by a semi-submerged whaling ship. If you didn't see the wreck, you were not to fly up the fjord because it would narrow to nothing and there was no way to turn around and no way to climb out.

Next day, soon after takeoff, I noticed that as I climbed, my engine temperatures were going up. The cowl flaps were stuck shut so that air couldn't circulate around the engines to cool them. Flipping the cowl flap control levers up and down, I dropped down to 200 feet above the water. I figured that the cowl flaps would come around after the engines had warmed up.

After cruising at 200 feet for three hours the cowl flaps had not come unstuck. I'd tried everything I could think of, even easing up to 2,000 feet and doing partial stalls. Nothing.

By this time the rest of the flight had climbed to 16,000 feet, the altitude needed to get over the ice cap at Greenland. Without oxygen, the guys were feeling the effects of anoxia, which was much the same as the effects of a few quick snorts. Radio silence had been merrily abandoned, and guys were singing sentimental ballads like "It Was Only an Old Beer Bottle" and "Mary Ann McCarthy, She Went Out to Dig Some Clams." Ainsley wanted me to come up and sing with them. He couldn't understand why I wouldn't, and I gave up trying to explain.

We were nearing our ETA for the coast of Greenland. Last night's horror movie replayed in my head. I would not fly up any fjord. I would try to get back to Iceland, and maybe a PBY Catalina could meet me and stay with me when I went down. I moved the throttles forward to climb and levered the cowl flap controls in desperation. They came unstuck. The flaps opened.

I climbed to 16,000 feet, looked at all the jagged ice sparkling in the sun, and went on over the ice cap to Bluie West One with the choral group. I had lost my flying jacket in Iceland and was in a gabardine summer flying suit, so after landing in Greenland I was shivering. Ainsley piled blankets over me in a bunk, and after a couple of hours I warmed up.

The rest of the way—from Greenland to Goose Bay, Labrador, to Bradley Field in Connecticut—was easy. All in all, the trip home was a lot scarier than the war.

—Arnold Benson

The Short, Unhappy Life of the Barling Bomber

NASM (SI NEG. #83-15013)

Too big, too slow, and way too expensive.

"From my lofty aerie I surveyed the structure of my gigantic plane," aircraft designer Walter H. Barling recalled of his view from the rear upper cockpit. "Before I was fully aware of it, we were taking off." Barling estimated his bomber, officially the U.S. Army Air Service's NBL-1, took off on its first flight on August 22, 1923, after a ground roll of only 13 seconds. Not bad for what was at the time the world's largest airplane.

NBL-1 had a larger wingspan and was taller than the Boeing B-17 of World War II. Its forest of struts and wires produced more drag than the Flying Fortress's clean form. And it had only half the B-17's horsepower. C.G. Grey, then editor of *All the World's Aircraft*, claimed that the NBL-1 "possibly has some value as a specimen of the world's worst aircraft."

Air Service Brigadier General William "Billy" Mitchell wanted a long-range, multi-engine airplane to carry bombs large enough to sink battleships. He told Congress in 1920 that the small bombs used against battleships were "about as effective…as throwing an egg at a tank" and that the Air Service now had bombs as large as 3,000 pounds in the works.

Barling, a consulting engineer at the Air Service's engineering division at McCook Field in Dayton, Ohio, designed a "Night Bombardment (Long-Distance)" airplane, to be powered by six of the Air Service's surplus Liberty 400-horsepower engines. On June 23, 1920, a $375,000 contract to build the Barling Bomber was awarded to Wittemann-Lewis Aircraft.

Construction began in early 1921 at the new plant of the renamed Wittemann Aircraft Corporation in Hasbrouck Heights, New Jersey. In October 1922, the result was broken down into sections and shipped to Wilbur Wright Field in Dayton.

When reassembled, the bomber stood 27 feet high and 65 feet long, with a wingspan of 120 feet. The middle wing, with a chord of eight feet, was five and a half feet narrower than the upper and lower wings, so the craft was sometimes called a "two-and-a-half-planer" rather than a triplane.

For landing gear, Barling introduced adjustable, multi-wheel trucks, similar to those used on transport aircraft today. The pilot could lower the front wheels of the two four-wheel trucks, and long-stroke oil-filled cylinders absorbed the initial impact of landing as the craft settled on the rear wheels and tail skid.

The gunner's cockpit was at the nose, and directly behind were the pilot and copilot at dual controls. The engineer's compartment was separated from the pilot's cockpit by control panels for the four tractor, or puller, engines and the two pusher engines.

NBL-1 set a world record in 1924 by carrying 9,000 pounds to 4,000 feet. However, for the aircraft to carry its maximum bomb load, 5,000 pounds, fuel had to be reduced, which limited the aircraft's range to less than 500 miles. With a top speed of 95 mph, the aircraft was "too slow even for an aerial funeral," Grey wrote.

General H.H. Arnold wrote in his memoirs that the Barling was abandoned after it could not climb over the Appalachian Mountains and still have enough fuel for a 400-mile Dayton-to-Washington trip. When Arnold assumed command of the Air Service depot at Fairfield, Ohio, in 1928, he found the Barling disassembled. Its enormous cost had kept it an object of interest to Congess, which denied Arnold's request to scrap it. He later submitted a vague request to "liquidate excess material," omitting any mention of the white elephant, and got the okay. "We immediately took the big ship out to the dump pile," he wrote, "where it was consumed in fire with the other obsolete, broken, and crashed airplanes. And that was the end of the Barling Bomber."

It was also the end of Wittemann Aircraft. The company had spent $528,000 to build the aircraft. The War Department promised to reimburse Wittemann for $200,000 worth of design changes, but it never paid up.

Walter H. Barling went on to bigger things. He retired from the Convair Division of General Dynamics in 1955, having helped develop the Air Force's giant B-36.

—Kevin L. Cook

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SEND IN THE GLOBAL HAWK

THE BIGGEST UAV WAS STILL BEING TESTED WHEN IT GOT THE CALL TO DUTY.

BY JOHN CROFT

John Casey, systems engineer, is an improbable warrior. And yet like many Americans struck by a rush of patriotism in the fall of 2001, he went off to war in Afghanistan and Iraq when the U.S. government asked for his help. "I had no military experience," he says, "aside from seeing some of my grandfather's World War II medals." A Purple Heart is among them.

Casey's weapon was his engineering knowledge of a Raytheon-built sensor system that captures images from an unmanned reconnaissance aircraft, the Global Hawk. Northrop Grumman had already delivered a series of Global Hawk prototypes to the Air Force for evaluation. As part of the program to assess their performance in high-altitude reconnaissance, Raytheon was contracted to deliver ground support equipment and the aircraft's sensors—but not Casey or his co-workers. The evaluation was scheduled to conclude in 2005, and if the Air Force gave a thumbs-up, production Global Hawks would either replace or complement piloted aircraft, like Lockheed's imaging recon U-2, in monitoring more traditional foes, such as North Korea. Ironically, the program had become mired in uncertainty and budget questions only one day before hijacked airliners were flown into buildings in New York and Washington.

The events of 9/11 changed everything, creating challenges and opportunities for both Casey and the Global Hawk. For Casey, change came in the form of a formal request from Northrop Grumman to Raytheon in the fall of 2001. The Air Force needed help mobilizing the Global Hawk for Operation Enduring Freedom, the multi-national effort to rid Afghanistan of Osama bin Laden and the Taliban. In particular, Northrop Grumman wanted Raytheon to find a way to reroute the Global Hawk on a moment's notice so it could zoom in on targets of interest.

Which was asking a lot. The Global Hawk had been designed to fly a route with the location of targets, the sensors of choice, and the resolution levels for the individual pictures programmed days or months ahead of time;

AUSTRALIAN GOVERNMENT, DEPARTMENT OF DEFENCE

The Global Hawk (right) has gone from a sketch on an envelope drawn by Alfredo Ramirez of Teledyne Ryan Aeronautical in the 1990s (reproduced opposite, bottom, from the original) to a high-flying star in the firmament of U.S. Air Force reconnaissance aircraft today. Ramirez has fared well too: He's now chief engineer for the aircraft.

OPPOSITE TOP: NORTHROP GRUMMAN

STAFF SGT. MATTHEW HANNEN/USAF

Eyes: For 50 years, the Lockheed U-2 has been a mainstay of aerial recon, combining endurance with an ability to operate at high altitudes.

NORTHROP GRUMMAN

Electro-optical imagers function as telescopes and sense light in both the visible spectrum and, here, the invisible infrared wavelengths.

the military calls such planned operation "flying the black line." But because the aircraft has a 50-megabit-per-second satellite communication link, the ground-based pilot could quickly change the Global Hawk's course and aim its sensors at a developing situation, and analysts receiving the sensors' data could suggest targets to commanders, who could send in the shooters within minutes.

The pilots don't really fly the Global Hawk so much as manage it. The aircraft's ground station uses computers instead of traditional flight controls, and a flight plan can be executed with a few clicks of a mouse. At the time of Enduring Freedom, the aircraft had some rerouting capability, but the software needed to revise the flight plan and aim the sensors was not in place, nor had the contract called for any.

Raytheon had just the ticket, however. The company had developed for its own use a Data Analysis Workstation, which put the sensors through their paces in the lab and on test flights. DAWS could be beefed up so that the Global Hawk could be redirected on the fly. The upgrade would require software modifications and a new workstation next to the Raytheon-built Mission Control Element, which originally was meant to house a pilot, a mission planning expert, and a communications engineer. The pilot had originally been tasked with managing the aircraft and the sensors in accordance with the black-line mindset; now, the MCE would have a sensor operator to share the workload.

The timeline was tight: Military planners wanted the revised system made combat-ready in 90 days. And they also would need some brave engineers who knew the DAWS inside and out—experts like Casey—to drop everything and take the system into battle as sensor operators.

Though catapulting a flight system from developmental status directly to war-ready standing is unusual, it is not without precedent, and the practice appears to be less of a taboo when it comes to unmanned aerial vehicles. Operation Enduring Freedom presented some formidable challenges that required some measured risk-taking. In testimony to Congress in 2003, Air Force Secretary James G. Roche recalled: "We go to General Franks [then commander of the U.S. Central Command]. And we said to him, 'We have a number of unmanned or unattended aircraft or remotely piloted aircraft that are not ready for prime time. May we employ them in Afghanistan and learn?' "

For the Global Hawk, early fielding looked like it might be worth the risk. When planners studied the Air Force's intelligence, surveillance, and reconnaissance plans for Afghanistan—taking into account the availability of aircraft like the U-2, the Rivet Joint electronic surveillance and warfare aircraft, and the Joint Surveillance Target Attack Radar System (better known as JSTARS), which monitors ground movement—they realized they would come up short for 24-hour, all-weather operations. The goal was seamless surveillance of the ground. Could the Global Hawk help? It certainly had the endurance.

TECH SGT. ROBERT J. HORSTMAN/USAF

In April 2001, Air Vehicle 5 (AV-5), the fifth of seven Global Hawk prototypes, became the first unmanned powered aircraft to cross the Pacific, flying from Edwards Air Force Base in California to Adelaide, Australia, on its way to participate in exercises with the U.S. Navy and the Royal Australian Air Force and Navy. The 7,500-nautical-mile transit set several world records and was eclipsed only by the Global Hawk's performance in the May and June exercises: Over a period of six weeks, the aircraft flew 13 out of 14 planned exercises, a total of nearly 10

The Global Hawk's performance in Australia matched what the Defense advanced Research Projects Agency had in mind when in the early 1990s it launched the Tier II+ program to build an unmanned aircraft with 24-hour endurance.

Ears: Teams of analysts aboard the RC-135 Rivet Joint monitor radio frequencies and advise commanders of an adversary's locations and intentions.

Raytheon trained the U.S. Air Force trainers: (left to right) Technical Sergeant John Jilcott, John Casey, Heather Dafnos, Ray Cochrane, Senior Airman Lacie Lambert, Daniel Scheffer, and Staff Sergeant Amanda Barnes.

RAYTHEON

days aloft, with some flights lasting more than a day.

The trip also gave planners the chance to try breaking out of the black-line box: Small civilian vessels under way in the area of operations served as unplanned targets that the aircraft was able to detect, track, and image. "We got a glimpse of how to interact with a pop-up target," says Ed Walby, Northrop Grumman's director of Global Hawk new business. Walby, a former Air Force colonel, is no stranger to high-altitude reconnaissance. In the mid-1990s, the U-2 pilot served as commander of the 99th Reconnaissance Squadron at Beale Air Force Base in California. Walby says that in those days, he and his fellow pilots would "pop the champagne" every time a UAV "screwed up." He told *Air Force News* at the time that he saw UAVs eventually complementing U-2s and other reconnaissance aircraft, "but not in the near future." As commander of the Global Hawk detachment during the Afghan and Iraq campaigns, Walby would have a change of heart.

The Global Hawk's performance and endurance in Australia matched what the Defense Advanced Research Projects Agency had in mind when in the early 1990s it launched the Tier II+ program, seeking a contractor that could build an unmanned aircraft with 24-hour endurance and an ability to operate at 65,000 feet, about 12 miles high and well above most light surface-to-air missiles, while collecting data with electro-optical, infrared, and synthetic-aperture-radar sensors. In 1995, having studied 14 proposals, DARPA selected the Teledyne Ryan Aeronautical Global Hawk. (Northrop Grumman acquired Teledyne Ryan Aeronautical in 1999.) The first flight of AV-1 took place at Edwards Air Force Base on February 28, 1998, after which the program shifted from DARPA to the Air Force; the program was managed by Wright-Patterson Air Force Base at Dayton, Ohio. Then problems crept in: AV-2 was destroyed on a test flight at Edwards after operators sent an incorrect command, and AV-3 was damaged after a software bug boosted the taxi speed to 178 mph instead of a placid 7 mph. AV-3 was fixed, and it returned to service in 2000 along with its new siblings, AV-4 and AV-5. The aircraft's first major cross-country flight took place that year, when AV-4 flew from Edwards to Eglin Air Force Base in Florida, then across the Atlantic to Portugal to support Operation Linked Seas, a NATO naval exercise, and two joint U.S. exercises involving a carrier bat-

tle group and Marine Corps expeditionary force. A year after Northrop Grumman acquired Teledyne Ryan Aeronautical, Global Hawk production moved from San Diego to Palmdale, California.

The Global Hawk is the latest in an increasingly complex lineage of aircraft that started with munitions delivery (carrying bombs), evolved into reconnaissance platforms, and now do both. U.S. experiments with UAVs in the 1940s included a project called Operation Aphrodite, which aimed to turn heavy bombers into unmanned radio-controlled missiles carrying tons of explosives. During the Vietnam War, Teledyne Ryan Firebee unmanned aircraft flew more than 3,400 missions providing reconnaissance, night photography, communications, electronic intelligence, leaflet dropping, and detection of SAM radar sites. During Operation Desert Storm in the Persian Gulf in 1991, the Navy and Marine Corps used Hunter and Pioneer UAVs, both derivatives of an Israeli system, to transmit battlefield images and help the Navy direct the 16-inch guns on the battleships USS *Wisconsin* and *Missouri*. Having seen the value of unmanned systems, the military funded advanced technology projects that produced the propeller-driven mid-altitude Predator and jet-powered high-altitude Global Hawk.

Air Force intelligence officials had concerns that the Global Hawk would actually provide too much data, swamping analysts with information and defocusing the effort. In a meeting on September 10, 2001, in the Office of the Secretary of Defense, there had been "turmoil" as to what direction the program should take, according to Ed Walby. It didn't help that the Pentagon's 2003 budget at the time had no funding for the program. The confusion didn't last long; the events of the following day upended priority lists. General John P. Jumper, Air Force chief of staff, gave the go-ahead to deploy the Global Hawk for the Afghanistan campaign. Once that decision was made, doubts were replaced by adrenaline. At Edwards Air Force Base, where Global Hawks arrive from Northrop Grumman's Palmdale assembly plant and are married to Raytheon sensors and tested with their transportable ground stations, engineers and technicians readied AV-3 and AV-5 for trips to the Persian Gulf, the launching point for missions over Afghanistan. At the same time, Raytheon engineers were rushing to ready the DAWS and a sensor operation workstation.

USAF

The Pioneer RQ-2C was a first-generation UAV used by U.S. forces in the 1980s.

The RQ-5 Hunter filled the services' UAV role in the '90s and since March 2003 has supported coalition forces in Operation Iraqi Freedom.

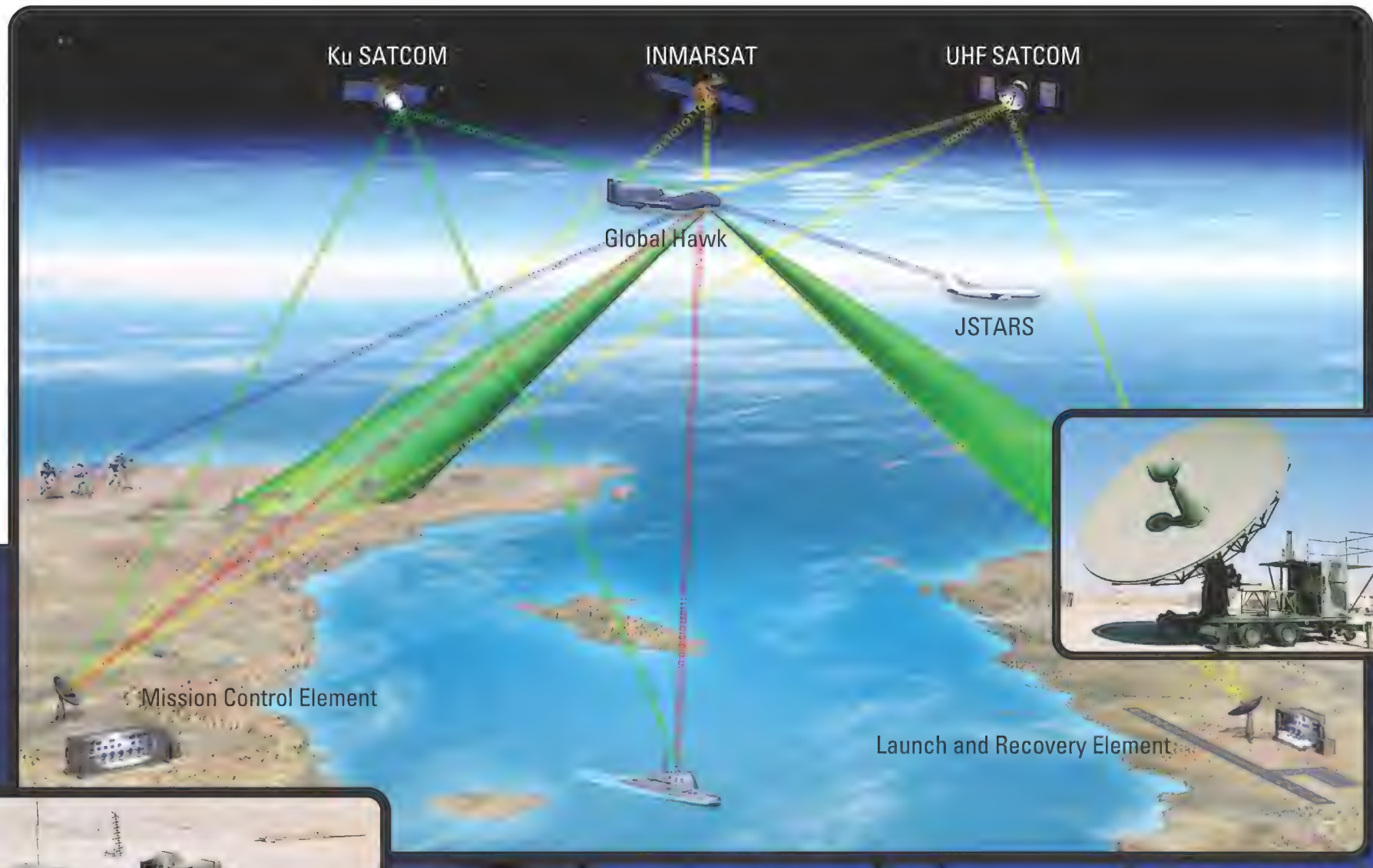
NASA

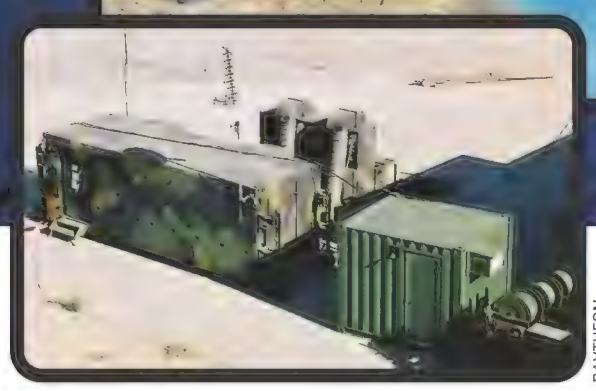
The air-launched, jet-powered Ryan AQM-34 family has been in operation since the Vietnam War.

USAF

During Operation Desert Storm in 1991, the Navy and Marines used Hunter and Pioneer UAVs, both derivatives of an Israeli system, to transmit battlefield images and help direct the 16-inch guns on the battleships USS *Wisconsin* and *Missouri*.

The Mission Control Element is a no-nonsense eight- by eight- by 24-foot windowless metal container with four workstations and room for a few observers. It was originally meant to be deployed by transport aircraft to a site near the action, but not too close. Along with a workstation for the pilot and a mission planning computer, the MCE has satellite and traditional radio communications. It also holds equipment that decompresses images downlinked from the Global Hawk and assembles them into mosaics, which are then transmitted to military analysts. The Launch and Recovery Element (LRE), an eight- by eight- by 10-foot container, is set up next to the vehicle's takeoff and landing site and manned by two operators and a mission director. Its equipment duplicates that of the MCE but adds a very precise differential GPS system, which refines the satellite nav-




RAYTHEON

Ground stations (left and right) anchor a vast data-link network (above) that spans the planet.

igation signals Global Hawk needs to taxi, take off, and land.

What these ground stations lack in aesthetics, the aircraft more than makes up for: The size of a business jet, the aircraft is oddly awkward and yet graceful, with its bulging fuselage and glider-like wings. It can carry a 2,000-pound payload aloft for up to 35 hours. The wings, built by Vought Aircraft Industries, are made of composite materials, as is the V-tail, built by Aurora Flight Sciences. The aluminum fuselage, built by Northrop Grumman, has pressurized compartments for the sensor packages and carries a single Rolls-Royce AE 3007H turbofan engine above the tail; two similar engines power the Cessna Citation X business jet (which coincidentally costs about the same as a Global Hawk *sans* ground elements and sensors—about $19 million). Mounted near the nose is Raytheon's side-looking X-band (the same wavelength as the weather radar on small jets) synthetic aperture radar, which can image single locations or track moving targets on the ground—the sensor of choice in bad weather, particularly sand storms in Iraq. The radar combines several snapshots of the ground to form a single higher-resolution image, thereby creating a virtual antenna—or "synthetic aperture"—many times larger than its actual antenna. Under the nose is the electro-optical camera, designed around charge-coupled devices similar to CCDs in video cameras; combined with it is a thermal imaging sensor—the instrument most suitable for finding people in mountainous areas, like Afghanistan.

According to Lieutenant Colonel James "Peewee" Wertz, commander of Edwards' 452nd Test Squadron, Global Hawk pilots have to be military or civilian pilots or air crew members, like weapons officers. Wertz was responsible for testing the completed aircraft and training its pilots until last October, when flight training moved to Beale Air Force Base. Because the aircraft essentially flies itself, training focuses mainly on learning how to manage the aircraft's systems and how to interact with other players, such as JSTARS and air traffic control. The pilots practice in simulations and live test flights at Edwards. Piloting skills are considered valuable: "There's still a certain amount of air sense you have to have to be able to manipulate the aircraft," says Wertz.

Buttoned up and ready to roll for Afghanistan in November 2001, the ground elements, with DAWS installed, hitched rides on Air Force heavy-lift aircraft—the MCE going to an undisclosed site in Germany and the LRE to a base somewhere in the Persian Gulf. At Raytheon, Casey and company were deploying stealthily as well. "We couldn't tell anyone where we were going," he says. "My parents had a phone number where they could reach me." He departed in June 2002 as a member of the second wave of Raytheon engineers headed for the MCE.

The two air vehicles took the high road, flying from Edwards to Australia to the Persian Gulf. While the aircraft was capable of making a nonstop flight,

NORTHROP GRUMMAN

EADS

A bulge atop the nose holds a satellite antenna and creates the "flying finger" look (above). Germany tested a radio listening package (right).

"to do that conveniently you have to fly over certain other countries that might be reluctant to let an unmanned vehicle fly over their airspace," says Robert Ettinger, Northrop Grumman's manager of Global Hawk flight testing. Once it arrived and set to work, its operators were taunted by manned-aircraft crews, who called the UAV the "Global Hog" because they thought its ground support infrastructure was excessive. But Walby points out that three U-2s providing 24-hour surveillance needed 157 support personnel, while one Global Hawk achieved the same result with a staff of only 25.

The aircraft operated in Afghanistan from November 11, 2001, to September 28, 2002, flying 60 combat missions totalling 1,200 hours and collecting 17,000 images. DAWS had turned out to be a stellar performer: By the third mission, 80 to 90 percent of the targets were unplanned—"ad hocs"—made possible by DAWS.

Casey returned home in August 2002, having suffered nothing more serious than a case of food poisoning. Some of the Global Hawks weren't as fortunate: AV-5 crashed while returning to its home base after a rudder control rod broke. AV-4 was sent in as a replacement, but it too crashed before the mission ended in September. According to Ettinger, AV-4 had an engine failure at altitude and was gliding to a landing in what looked like an obstacle-free flat area in Pakistan. Unfortunately, a 100-foot sand dune occupied the space that the maps showed to be clear.

Afghanistan, as it turned out, was just a warm-up for Operation Iraqi Freedom, which started in early 2003. The Enduring Freedom learning curve in Afghanistan had generated improvements: With its broadband satellite connections now proven, the MCE no longer needed to be located in-theater and was moved to Beale Air Force Base. Also, everyone involved in the "sensor-to-shooter" decision process now had a "chat room," or instant messaging capability, which proved more useful than traditional telephone lines. In the air over Iraq would be the veteran AV-3, the lone surviving Global Hawk, with a full complement of sensors.

Raytheon's role in Iraqi Freedom had changed as well: The Air Force wanted the company's experts to give its officers classroom and on-the-job training during the conflict. With 90 days of "combat" experience using DAWS, Casey was picked to teach the teachers; he spent two weeks at Beale during the initial stages of the Iraq operation. His digs were much nicer on this side of the ocean. "They had CNN. They had e-mail. They had coffee. They had Pop Tarts," he says.

By itself, AV-3 identified

55 percent of the of the time-sensitive targets, located 13 complete SAM batteries, more than 50 SAM launchers, 300 SAM canisters, and more than 70 SAM transporters. And it provided intelligence that led to the destruction of more than 300 tanks—38 percent of Iraq's known armored force.

NORTHROP GRUMMAN

ROBIN HICKS/USAF

Air Force Secretary James Roche (right) reported that images of a troop movement, like the one at left, enabled coalition forces to neutralize Iraqi armor. The Global Hawk's radar sees through cloud and has a moving-target indicator mode that detects targets moving as slowly as five miles per hour.

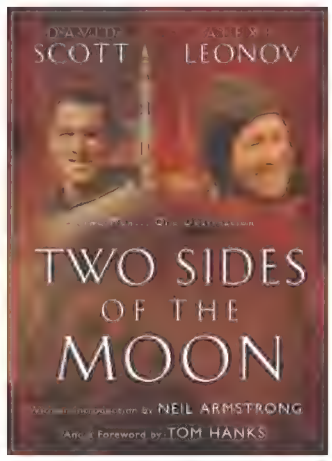
Once the action started, though, the MCE became the pressure-cooker it resembles. When sandstorms raged in late March, reducing ground visibility to near zero, a JSTARS radar system pierced the sand clouds and picked up troop movement south of Baghdad. In the hours that followed, the Global Hawk team was called in for its most acclaimed mission of the war. According to Air Force Secretary Roche, JSTARS had found a line of troops and equipment moving in, using the sandstorm as cover, to reinforce the much-feared Republican Guard Medina Division. The handoff from the JSTARS to AV-3 allowed analysts connected by satellite and chat links at the Air National Guard's 152nd Intelligence Squadron in Reno, Nevada, to see through the storm and help the air operations experts in Qatar guide fighter and bomber aircraft with GPS-guided bombs to the scene; the Medina Division was essentially neutralized.

When AV-3 returned to Edwards on May 5, 2003, the mission success symbols painted on its nose didn't quite trumpet what the team had accomplished in only eight weeks. AV-3 alone identified 55 percent of the time-sensitive targets and led to significant destruction of Iraqi air defense equipment. It located 13 complete SAM batteries, more than 50 SAM launchers, 300 SAM canisters, and more than 70 SAM transporters. And it provided the intelligence that led to the destruction of more than 300 tanks—38 percent of Iraq's known armored force.

While Casey is once again manning a computer at Raytheon, AV-3 continues to scour the mountains of Afghanistan, having gotten another call to duty in March for Operation Mountain Storm. Walby says its toolbox continues to grow, the latest addition being Advanced Information Architecture. With AIA, soldiers with laptops or personal digital assistants—PDAs—can use the secure chat room or a radio link to request imagery from the Global Hawk pilot, who can respond by downlinking digital maps stored in the aircraft's 1.4-terabyte server. "It works precisely like [the Internet's] MapQuest," says Walby.

Managers of the Global Hawk believe the program has found its footing. The three prototypes based Stateside are completing the aircraft's long-postponed flight test program at Edwards, while five Air Force and two Navy production models are being built in Palmdale. An upgraded version with a 3,000-pound payload capacity and longer wings (130.9 feet) is also in the works, with deliveries starting next year. The Air Force alone has ordered 51 aircraft. The number could grow as other government agencies and countries, such as Australia and Germany, consider purchases. The company hopes to highlight the Global Hawk's achievements by flying the aircraft to next year's Paris Air Show, retracing the 1927 route Charles Lindbergh flew in his Ryan-built *Spirit of St. Louis*.

As for Casey, he's moved on to other programs at Raytheon, satisfied in part because he's served his country. He also has his own bits of war memorabilia, his favorite being a very small metal pin that was carried aloft in a Global Hawk during Operation Enduring Freedom. On it is an image of an American flag.



From the book Two Sides of The Moon *by David Scott and Alexei Leonov. ©2004 by the authors and reprinted by arrangement with Thomas Dunne Books, an imprint of St. Martin's Press, LLC.*

THE NIGHTMARE OF VOSKHOD 2

COSMONAUT ALEXEI LEONOV RECALLS THE MOST HARROWING SPACE MISSION OF HIS CAREER.

In March 1965, at the age of 30, Soviet cosmonaut Alexei Leonov made the first spacewalk in history, beating out American rival Ed White on Gemini 4 by almost three months. Floating outside his tiny Voskhod 2 capsule for 10 exhilarating minutes, Leonov felt, he writes, "like a seagull with its wings outstretched, soaring high above the Earth." In keeping with the secrecy of the Soviet space program, few people—not even his family—knew about the spacewalk ahead of time. Even less well known was how close Leonov and his crewmate, Pavel (Pasha) Belyayev, came to dying that day. In his recently published book, Two Sides of the Moon, *written with U.S. Apollo astronaut David Scott, Leonov recounts the spacewalk and its even more dramatic aftermath.*

When my four-year-old daughter, Vika, saw me take my first steps in space, I later learned, she hid her face in her hands and cried.

"What is he doing? What is he doing?" she wailed. "Please tell Daddy to get back inside."

My elderly father, too, was upset. Not understanding that the purpose of my mission was to show that man could survive in open space, he expressed his distress to journalists who had gathered at my parents' home.

"Why is he acting like a juvenile delinquent?" he shouted in frustration. "Everyone else can complete their mission properly, inside the spacecraft. What is he doing clambering about outside? Somebody must tell him to get back inside immediately. He must be punished for this."

His anger soon gave way to pride when he heard a live broadcast of President Leonid Brezhnev's message of congratulations beamed up to me from the Kremlin via mission control.

"We members of the Politburo are here sitting and watching what you are doing. We are proud of you," Brezhnev said. "We wish you success. Take care.

Opposite: Scenes from the first spacewalk. Leonov was awestruck gazing down at the "gigantic, colorful map" below, but the ballooning of his spacesuit (note glove, lower left) made it hard to squeeze back in the airlock.

ALL PHOTOGRAPHS COURTESY OF THE AUTHORS AND NASA

Before the Soviet lunar program stalled out, Leonov (shown prior to the launch of Soyuz 19 in 1975) was in line to become the first cosmonaut on the moon.

We await your safe arrival on Earth."

As I pulled myself back toward the airlock, I heard Pasha talking to me: "It's time to come back in." I realized I had been floating free in space for over 10 minutes. In that moment my mind flickered back for a second to my childhood, to my mother opening the window at home and calling to me as I played outside with my friends, "Lyosha, it's time to come inside now."

With some reluctance I acknowledged that it was time to reenter the spacecraft. Our orbit would soon take us away from the sun and into darkness. It was then I realized how deformed my stiff spacesuit had become, owing to the lack of atmospheric pressure. My feet had pulled away from my boots and my fingers from the gloves attached to my sleeves, making it impossible to reenter the airlock feet first.

I had to find another way of getting back inside quickly, and the only way I could see to do this was pulling myself into the airlock gradually, head first. Even to do this, I would carefully have to bleed off some of the high-pressure oxygen in my suit, via a valve in its lining. I knew I might be risking oxygen starvation, but I had no choice. If I did not reenter the craft, within the next 40 minutes my life support would be spent anyway.

The only solution was to reduce the pressure in my suit by opening the pressure valve and letting out a little oxygen at a time as I tried to inch inside the airlock. At first I thought of reporting what I planned to do to mission control. But I decided against it. I did not want to create nervousness on the ground. And anyway, I was the only one who could bring the situation under control.

But I could feel my temperature rising dangerously high, with a rush of heat from my feet traveling up my legs and arms, due to the immense physical exertion all the maneuvering involved. It was taking far longer than it was supposed to. Even when I at last managed to pull myself entirely into the airlock, I had to perform another almost impossible maneuver. I had to curl my body around in order to close the airlock, so Pasha could activate the mechanism to equalize pressure between it and the spacecraft.

Once Pasha was sure the hatch was closed and the pressure had equalized, he triggered the inner hatch open and I scrambled back into the spacecraft, drenched with sweat, my heart racing.

The serious problems I had experienced when reentering the spacecraft were, thankfully, not televised. From the moment our mission looked to be in jeopardy, transmissions from our spacecraft, which had been broadcast on both radio and television, were suddenly suspended without explanation. In their place Mozart's Requiem was played again and again on state radio. My family was therefore spared the anxiety they would have had to endure had they known how close I came to being stranded in space. They were also spared the trauma they would have suffered had they known the grave danger that Pasha and I faced in the hours that followed. For the difficulties I experienced reentering the spacecraft were just the start of a series of dire emergencies that almost cost us our lives.

Just five minutes before our retro-engine was due to start dropping us out of orbit, I checked our instruments and realized our automatic guidance system for reentry was not functioning correctly. We would have

Voskhod 2 was Leonov's first spaceflight. Before becoming a cosmonaut, he flew MiGs.

to switch off the automatic landing program. This meant we would have to orient the spacecraft before reentry manually, and would also have to select our landing point manually and decide on the exact timing and duration of the retro-rocket firing. We knew our landing would have to be performed during our next orbit and that, despite our best efforts, we would be coming down off-target—1,500 kilometers [930 miles] west of where we were supposed to land.

As our orbit brought us above the Crimea, we received the first ground control communication we'd had in some time. "How are you, Blondie? Where did you land?" It was Yuri Gagarin; he always called me "Blondie." It was good to hear his voice. Even in such difficult circumstances he sounded full of warmth, even relaxed. But from what he was saying, it was clear mission control thought we had already landed.

After their return, Leonov and Pavel Belyayev (in military dress) appeared with President Leonid Brezhnev and party leaders.

As I pulled myself back toward the airlock I heard Pasha talking to me: "It's time to come back in." At that moment my mind flickered back to my childhood, to my mother opening the window and calling to me as I played outside with my friends, "Lyosha, it's time to come inside now."

Pasha clicked on his microphone. "We had to turn off the automatic landing system. We have only enough fuel to do one correction, and besides that, the indicator shows that the main engine for reentry is very low on fuel," Pasha reported in as steady a voice as he could. "We can make only one attempt at reentry. We are asking you therefore to go into emergency mode."

It was my job, as navigator, to determine where we would land. Our orbit would take us right over Moscow; we could set down in Red Square. But we had to choose somewhere as sparsely populated as possible. I decided on an area close to the city of Perm, just west of the Ural Mountains. Even if I miscalculated and our orbit took us beyond Perm, we should still be able to land in Soviet territory. We could not run the risk of overshooting so much that we came down in China; relations with the People's Republic were poor at the time.

Pasha began orienting the craft for reentry. This was no easy task—in order to use the optical device necessary for orientation, he had to lean horizontally across both seats in the spacecraft, while I held him steady in front of the orientation porthole. We then had to maneuver ourselves back into the correct positions in our seats very rapidly so that the spacecraft's center of gravity was correct during the reentry burn. As soon as Pasha turned on the engines we heard them roar and felt a strong jerk as they slowed our craft. According to the flight schedule, our landing module would separate from the orbital module 10 seconds after retro-fire. I counted the seconds down in my head.

But something was very wrong. It felt as if we were being dragged from behind, as if something was pulling us back. When we began to reenter the Earth's atmosphere, we started to feel gravity pulling us in the opposite direction. The conflicting forces—my instruments indicated 10 Gs—were so strong that some of the small blood vessels in our eyes burst. Looking out my window, I realized with horror what was happening. A communication cable connected the landing module with the orbital module, and as we rapidly entered the denser Earth atmosphere, the cable had become the two modules' common center of gravity, and we were spinning around it.

The spinning eventually stopped at an altitude of about 100 kilometers, when the connecting cable burnt through and our landing module slipped free. Then we felt a sharp jolt as first the drogue chute and then the landing chute deployed. Everything became very peaceful, very calm. We could hear and feel the wind whistling in the straps as the module swung gently on the landing chute.

Suddenly everything became dark. We had entered cloud cover. Then it grew even darker. I started to worry that we had dropped into a deep gorge. There was a roaring as our landing engine ignited just above the ground to break the speed of our descent. Finally we felt our spacecraft slumping to a halt. We had landed in two meters of thick snow.

Our orientation system indicated that we had landed 2,000 kilometers beyond Perm, in deepest Siberia. "How soon do you think they'll pick us up?" Pasha asked me, concerned, as the landing module shuddered to a standstill.

I tried to make light of our situation. "In three months, maybe, they'll find us with dog sleighs."

A skilled artist, Leonov took pencils and a sketch pad to orbit, and later painted this view of his spacewalk.

We had to get out of the spacecraft to assess our location, but that was not easy. When we flicked the switch to open the landing hatch, the explosive bolts holding it shut were activated and a smell of gunpowder filled the cabin. But, though the hatch jerked, it failed to open. Looking out of the window, we could see the hatch was jammed against a big birch tree. We had no alternative but to start rocking the hatch violently back and forth, trying to shift it clear of the tree. Then, using all his strength, Pasha managed to push the hatch away from the remains of the bolts, and it slid back and disappeared into the snow.

We took in a deep draught of fresh air and felt our lungs contract with the sudden blast of cold. After so many emergencies, the relief at drawing breath on Earth again was indescribable. We threw our arms round each other, slapping each other on the back as best we could in our bulky spacesuits.

It was my job, as navigator, to determine where we would land. Our orbit would take us right over Moscow: We could set down in Red Square. But we had to choose somewhere as sparsely populated as possible. I decided on an area close to the city of Perm, just west of the Ural Mountains.

We both squeezed out through the hatch, and sank up to our chins in snow. Looking up, we could see we were in the middle of a thick forest, a *taiga* of fir and birch. I tried to determine our approximate location by measuring the sun's height above the horizon. But it soon disappeared behind the clouds. The sky grew darker and it started to snow, so we sought shelter back in the spacecraft.

Fortunately, Pasha and I were used to harsh climates. He had been born in the Vologda region, north of Moscow, and had spent much of his childhood hunting in the forest close to his home; his first ambition had been to become a hunter. I, dreaming of becoming an artist, had spent my childhood in central Siberia.

We were only too aware that the *taiga* where we had landed was the habitat of bears and wolves. It was spring, the mating season, when both animals are at their most aggressive. We had only one pistol aboard our spacecraft, but we had plenty of ammunition. As the sky darkened, the trees started cracking with the drop in temperature—a sound I was so familiar with from my childhood—and the wind began to howl.

Even though mission control had no idea where we were or whether we had survived, our families were informed that we had landed safely and were resting in a secluded *dacha* before returning to Moscow. Our wives were advised to write us letters welcoming us home.

We had no idea if our rescue signal had been received. It turned out later that Moscow had not received it, but it had been picked up by listening posts as far away as Bonn, Germany. More importantly, a cargo plane flying close to our landing site had also picked it up. A search party had been dispatched, and late in the afternoon, we picked up the sound of a helicopter approaching. We plowed through the thick snow into a clearing and stood waving our arms. The pilot spotted us. But we soon realized it was a civil aircraft, not a military one. He and his crew would have no idea how to rescue us.

They saw it differently. Eager to help, they tossed a rope ladder down to us

and signaled that we should grab it and clamber aboard. It was impossible. It was a flimsy ladder and our spacesuits were too heavy and stiff to allow us to scale its rungs.

As news of our whereabouts was relayed from pilot to pilot in the area, more aircraft started to circle above us. There were so many at one point that we worried one would collide with another. But the pilots meant well. A bottle of cognac was tossed out of one plane; it broke when it landed. A blunt axe was thrown from another. Of far more use were two pairs of wolf-skin boots, thick pairs of trousers, and jackets. The clothes got caught in branches, but we managed to retrieve the warm boots and pulled them on.

But the light was failing fast and we realized we would not be rescued that night. We would have to fend for ourselves as best we could. As it grew darker the temperature dropped rapidly. The sweat that had filled my spacesuit while I was trying to reenter the capsule after my spacewalk was sloshing around in my boots up to my knees. It was starting to chill me. I knew we would both risk frostbite if we did not get rid of the moisture in our suits.

We had to strip naked, take off our underwear, and wring the moisture out of it. We then had to pour out what liquid had accumulated in our spacesuits. We went on to separate the rigid part of the suit from its softer lining—nine layers of aluminum foil and a synthetic material called dederone—and then put the softer part of the suits back on over our underwear and pull our boots and gloves back on. Now we could move more easily.

We tried for a long time to pull our capsule's vast parachute out of the trees so we could use it as extra insulation. It was exhausting work, and we were forced to rest briefly in the snow. But as it grew even darker, the temperature dropped further still, and it began to snow much more heavily. There was nothing to do but return to the capsule and try to keep as warm as we could. We had nothing to cover the gaping hole left by the detached exit hatch, and we could feel our body heat dropping sharply as the temperature plummeted to below –22 degrees Fahrenheit.

The next morning we woke to the sound of an airplane circling overhead. Above the roar of the engines we could just hear voices in the distance. I took a signal gun and fired a flare. Slowly, a small group of men on skis came into view. Led by local guides, the rescue party included two doctors, a fellow cosmonaut, and a cameraman, who began filming as soon as he saw us.

It was to be another 24 hours before another team of rescuers could chop down enough trees to make a clearing big enough for a helicopter to land. We would have to survive another night in the wild, but this night was a great deal more comfortable than the first. The advance party chopped wood and built a small log cabin and an enormous fire. They heated water for us to wash in a large tank flown in especially by helicopter from Perm. And they laid out a supper of cheese, sausage, and bread. After three days with little food, It seemed like a feast.

By the next morning, we were ready to ski nine kilometers to a clearing where a helicopter was standing by to fly us to Perm. From there we were flown to our launch site at Baikonur, where we disembarked to find a large group waiting for us, headed by Sergei Korolev, our chief, and Yuri Gagarin. At first they looked serious, and seemed confused by our heavy jackets, polar hats, and wolf-skin boots. But as we approached, their faces suddenly broke into broad smiles. We hugged each other, laughed, and joked.

We were then driven in an open-top jeep to the town of Leninsk, followed by a motorcade that stretched for several kilometers. A government committee was awaiting our arrival, ready with many questions about our 26-hour spaceflight. We had to deliver reports on how our mission had gone. Mine was brief and to the point: "Provided with a special suit, man can survive and work in open space. Thank you for your attention."

On his last trip to orbit, Leonov and Valery Kubasov (far right) flew the Soviet half of the 1975 Apollo-Soyuz mission.

By the 1970s, Leonov had a chest full of medals and a coveted job as chief of cosmonaut training.

Blue force F-15s inbound to a target hug the terrain on the vast training range at Nellis Air Force Base in Nevada (above). Real smoke and flame (but not live air-to-air ammo) add thrills.

FORCE ON IMAX

A pair of attacking A-10s pop flares designed to confuse infrared (heat) seeking missiles.

PHOTOGRAPHS COURTESY MARIO RACHELE

On IMAX screens 80 feet high, lifesize fighter jets practice for the real thing.

Unless you were a U.S. or allied military pilot, you could never hope to get a front seat to view a Red Flag exercise, the intense air combat training held at Nevada's Nellis Air Force Base. Now an IMAX® film produced by Stephen Low and Pietro Serapiglia will provide audiences in large-format theaters worldwide with the sights and sounds of the world's most exciting aerial arena.

Fighter Pilot: Operation Red Flag, sponsored by Boeing, will premiere on December 9 at the National Air and Space Museum's Steven F. Udvar-Hazy Center at Dulles International Airport in Virginia, just in time for the first anniversary of the facility's opening. Audiences will experience events through the eyes of an actual fighter pilot, U.S. Air Force Captain John Stratton.

Airborne IMAX cameras capture the whirling action as blue (friendly) and red (not so friendly) forces tangle. The blues' mission is taking out ground targets, while the reds, made up of Nellis' Adversary Tactics Division pilots, who are trained in the tactics used by hostile nations, defend against the attack. Since it was started in 1975, Red Flag is estimated to have trained some 400,000 U.S. and allied military air crew members.

The training is as realistic as the instructors can make it without deliberately putting the participants in life-threatening situations. The range can confront pilots with electronic jamming, simulated anti-aircraft missiles and artillery, and hostile radar sites. Even though Red Flag is a simulation, Stratton says, the pilots' stress level is as high as or higher than it is in actual combat. And being told you've been shot down is a real low.

At the heart of the training is the sophisticated Nellis Air Combat Training System, or NACTS, engineered by the Cubic Corporation. NACTS can track up to 100 aircraft in the restricted airspace

over Nellis' vast desert training ranges. Each aircraft carries a sensor and communication pod, and transmissions from the sensors, as well as the pilots' radio transmissions, are picked up by ground stations scattered throughout the huge training range. A central computer records the action for replay during classroom debriefings. During these sometimes frank sessions, each pilot gets to re-experience decisions that led to scoring or being scored upon.

Fighter Pilot explores almost all aspects of the weeks-long Red Flag experience, from the classroom to all-night maintenance sessions, from fire drills to search-and-rescue operations. The 40-plus-minute IMAX experience is an action catalog of U.S. and allied fighters, along with the tankers, transports, and helicopters that support their mission. And Stratton himself has a back story that forms the bookends for the film: His grandfather was a Vought F4U Corsair pilot and recipient of the Distinguished Flying Cross during World War II, inspiring Stratton to pursue an Air Force career.

With their eight-story screens and digital audio systems, IMAX theaters provide the best way for viewers to experience the intensity of air-combat action. The dates when *Fighter Pilot: Operation Red Flag* will open in IMAX theaters are still tentative; check *www.airspacemag.com* for a schedule and for additional locations as more dates become firm.

—The Editors

COURTESY CUBIC CORPORATION

U.S. Air Force Lieutenant Colonel Steve "Carlos" Satava replays a battle in the Individual Combat Aircrew Display System theater (above). HH-60 Pave Hawks lend reality to the action with search-and-rescue drills (below).

A Douglas DC-2 moons at the 717 factory across the street. Designed just after Boeing's 247, the abler DC-2 vanquished its competitor. Douglas Aircraft tried the same strategy with its first jetliner, but the DC-8 did not prevail.

CHAD SLATTERY

VITAL SIGNS

LONG BEACH STRUGGLES TO KEEP ITS ASSEMBLY LINES ALIVE.

BY MARK HUBER

It's 10:30 Tuesday morning. Two dozen retired engineers and managers, men mostly in their 70s and 80s, are assembling in The Prop Room, a small restaurant at the Long Beach, California airport. They greet one another heartily, order cocktails, tell ribald jokes, and dish out pointed gibes. Some wear numbered badges, the numbers corresponding to the departments they worked for at the mammoth Douglas Aircraft plant a few blocks away.

Donald Douglas Jr. had been an infrequent attendee at these weekly gatherings until his death on October 3, at 87. When I met him at one of the luncheons—he had been driven in from his home in Temecula—he had two American flags pinned on his long-sleeve shirt and a button that said, "I survived damn near everything." He had. He had spent his career in the shadow of his father, Donald Wills Douglas, who built the Douglas Aircraft Company into a titan that ruled the commercial airplane industry for three decades and during World War II pro-

duced 9,441 military aircraft at its Long Beach factory alone. Donald Jr. inherited the day-to-day management of the company when he became president in 1957 (his father continued as chairman), smack in the middle of the battle with Boeing over the market for the first U.S. jetliners. He presided while the company fell behind with the DC-8 and won back market share with the DC-9, then watched it all come unglued. In 1967, when Douglas was flush with orders, the company ran $400 million short on cash, saw its stock tank, and was bought by military contractor McDonnell at bottom-feeder prices. Over the next 30 years McDonnell Douglas would gradually cede the commercial aircraft market to Airbus and Boeing.

Douglas' 500-acre factory complex, straddling Lakewood Boulevard, made Long Beach a prominent aircraft manufacturing center for 45 years—until the end of the cold war shut down many of California's military-related industries, and the fallout from the 1974 deregulation of the airline industry drifted down to the manufacturers. Between 1990 and 1994, the Long Beach factory cut 30,000 jobs from a workforce of 52,000.

Bill Schultz is the president of United Auto Workers Local 148, the largest union at Long Beach. He accepted the layoffs as the inevitable result of a global economic downturn and the worst airline slump in the history of the industry. (U.S. airlines alone reported $9 billion in losses in 1990 through 1993, the first time since World War II that world air traffic declined.) "The aerospace industry has always been cyclical," Schultz says. "Boeing went through the same cycle." But more layoffs came at the end of the decade.

In 1997, Boeing bought McDonnell Douglas, and managers decided to shut down the Long Beach lines for the twinjet MD-80 and -90 airliners, both derived from the DC-9 and both competitors of Boeing airplanes. Four years after Boeing took over, the company eliminated the long-range tri-jet MD-11 (descended from the DC-10). Those decisions cut thousands more jobs. "Closing down the heritage McDonnell Douglas lines," says Schultz, "that's been as traumatic" as the earlier, larger cutbacks.

After the Boeing buy, workers and city officials had hoped that Long Beach would be a contender for Boeing's next airplane, the 250-seat 7E7 Dreamliner. But California was caught in a financial crisis of its own and couldn't match the $4 billion package of tax and other incentives that Washington state offered Boeing. The 7E7 not surprising-

BOEING HISTORICAL ARCHIVES

Sparkling success story: The C-17 line (above) has won business and manufacturing awards. Left, top: A one-ton globe once symbolized the Douglas Aircraft Company's world dominance. Today, former Douglas buildings are being demolished to make way for a commercial park.

CHAD SLATTERY (2)

BOEING HISTORICAL ARCHIVES

Donald Douglas Jr. (1917–2004) followed in the footsteps of an aviation legend and led his company into the Jet Age.

Right: McDonnell Douglas DC-10s lined up for delivery at the Long Beach plant. (Note the liveries of two airlines that no longer exist—National and Laker.) The DC-10 went head to head with Lockheed's wide-body, the L-1011. Though the TriStar didn't sell as many copies, it took away enough of the market to make the DC-10 a loser.

ly went to Boeing's hometown, Everett.

Locals now accept that commercial aircraft production at the old Douglas plant will never return to its pre-1990 vigor. The final sign: The Boeing Realty Corporation is demolishing buildings on the west side of Lakewood Boulevard to make room for Douglas Park, a 260-acre office, retail, housing, and hotel complex. On the east side of Lakewood, one commercial production line still runs, filling orders for the 106-seat Boeing 717.

Every week the retired executives who congregate at The Prop Room watch the progress of the demolition on their way to lunch. "I spent a lot of time in those buildings," says 88-year-old Bill Losch, who started as a $13-a-week draftsman with Douglas' Santa Monica operation in 1936 and retired as assistant to the vice president of sales in 1980. He remembers that in 1941, the year the Long Beach plant opened, a thousand A-20s came out of one of those now-leveled structures west of Lakewood. "It makes me mad," he says of the demolition. "The U.S. government should never let a prime military plant go under, period." Losch wonders where the government will get such manufacturing capacity if it's needed again. "I've seen plants torn down all over southern California that should have been kept open," he says.

"It's about 75 percent torn down," says Bob Eddington, president of the 7,000-member retiree chapter of UAW Local 148. Eddington retired in 1993 after 39 years at the Long Beach plant as a machinist, working in Buildings 3 and 5. "They were some of the first ones to go," he says.

"They have sentimental value, but there is nothing historically significant about them," Boeing spokesman Bill Wasserzieher says of the structures being taken down. He points out that Boeing has preserved the neon "Fly DC Jets" sign atop the 717 assembly building because the company considers it a piece of aviation history. Wasserzieher, who has been with the company "since the McDonnell Douglas days," is himself sentimental about the Long Beach plant. "They were such great planes," he says of the airliners Douglas built. He reminds me that besides the indomitable DC-3, the DC-6 and -7 were favorites of the airlines and that many DC-8s fly freight to this day.

The company sometimes struggled to build them. "We had a cash flow problem," says John Rapillo, 83, a DC-8 deputy program manager who retired in 1981. The problem was that the DC-8 cost too much to develop and too much to build. According to Wilbur H. Morrison, author of the Douglas biography *A Heart With Wings*, "The company spent more money developing the DC-8's landing gear than it spent developing the entire DC-3." When customers found that the earliest models of the jet didn't deliver the fuel economy promised, Donald Sr. knocked down the price and directed a costly redesign. In the 1960s, when Douglas was producing the four-engine DC-8 and the smaller twin-jet DC-9, labor costs rose out of control, aircraft parts were in short supply, and production fell hopelessly behind schedule. Rapillo recalls seeing DC-8s roll down the assembly line on steel wheels and rails because "we had no landing gears." Rapillo blames the company policy of relying on a single supplier for each component. The problems continued after the Douglas Aircraft Company became part of the McDonnell Douglas Corporation. Douglas Jr. blamed the Vietnam War for diverting resources from the manufacture of passenger

BOEING HISTORICAL ARCHIVES

Although Douglas DC-9 production began with zero orders, the short-haul jet became popular with airlines around the world, as the parade of flight attendants indicates. Below: On the Long Beach plant's 1941 opening day, a B-19 flew over a crowd of 30,000.

jets to the production of military aircraft, chief among them the F-4 Phantoms built at McDonnell's St. Louis plant. Whatever the cause, unfinished airliners began to pile up on the Long Beach ramp.

Even in those troubled times, the employees were proud of the Douglas reputation. "We used to walk away from meetings with guys in other companies like Lockheed and Convair with an air of superiority," says Rapillo.

Bette Murphy, a past president of the Local 148 retiree chapter, joined the company in 1942 as a Rosie the Riveter, and was a shop steward in 1949. Eventually she served four terms on the contract bargaining committee, and helped lead the union through four strikes. "I learned how to negotiate with the company," she says. "Back then, they'd open the books and show you how things were going, and you'd say, 'Oh well, if that's the case. You can't get blood out of a turnip.'

"I got along well with Mr. Douglas. I remember he used to come out [to the shop] and say, 'Hi, Red'—because of my red hair—'How's it going?' They cared about people. His wife donated all the money from the soda machines so I could get flowers [for the union members] if somebody had a baby or went to the hospital or something."

During the 1980s, McDonnell Douglas held its own against Boeing, as the Long Beach factory cranked out the successful MD-80 series, stretched versions of the DC-9, and the shorter-fuselage MD-90. American Airlines acquired more than 250 MD-80s, making the type the backbone of its fleet. Worldwide, the MD-80 remains one of the most plentiful airliners in service.

BOEING HISTORICAL ARCHIVES

But McDonnell Douglas had nothing that could compete with Boeing's phenomenal 747. Its own wide-body, the tri-jet MD-11, sold disappointingly, and by the mid-1990s, McDonnell Douglas' commercial lines were in trouble. The company's plight showed clearly in the sales figures from the 1996 Farnborough Airshow. Customers ordered $11.7 billion worth of airliners; Boeing snared $7.2 billion, Airbus got $3 billion, and McDonnell Douglas came in third with $710 million.

In the meantime, workers at the Long Beach factory struggled to improve production, and succeeded—with a military program, the C-17 Globemaster III jet transport. Capable of being refueled in flight, the Globemaster III can carry 160,000 pounds nonstop from a U.S. base to unimproved, 3,000-foot airstrips in places like Afghanistan. McDonnell Douglas won a contract for 120 of the airlifters in 1980, but because of cost overruns and poor quality control, the Pentagon considered scrapping the program. McDonnell Douglas and U.S. Air Force managers turned the program around. In August 2002, five years after Boeing took over, the Air Force extended its order to 180

CHAD SLATTERY

Retired Douglas executives convene weekly meetings at The Prop Room.

aircraft, enough to keep production going through 2008. In December 2002, the program was given the U.S. Senate's Productivity Award for performance excellence.

On the commercial side, the facility turned out 1,200 MD-80s and -90s between 1980 and 1999. Structure mechanic Charles Perrin, 59, is a second-generation employee of the plant. He started work at Douglas in 1966; his father worked there from 1952 to 1968. Among other jobs, Perrin led a team building the horizontal stabilizer for the MD-90. "We built the whole thing from scratch," he says. "We had our own machine shop. McDonnell Douglas put some of us through self-directed team leadership training so the team leader could run the shop. We were building the horizontal [tail] in 2,800 hours, and we got it down to 1,800 hours. We wanted to do it without management being in the way."

Bette Murphy joined Douglas in 1942, helping to blaze a trail for women who would assemble aircraft like the MD-11 (below).

CHAD SLATTERY

RIGHT: BOEING HISTORICAL ARCHIVES

Another employee, who asked not to be identified, says that McDonnell Douglas "had not been good about modernizing the facilities" and that the number of hours spent building the MD-80 "just did not come down to where they should have been."

After Boeing acquired McDonnell Douglas, one commercial product survived: the 717. How long it can continue is another matter.

From the outside, the differences between a Douglas DC-9 and a Boeing 717 are almost imperceptible. The 717 has bigger engine nacelles and a faired tail cone and lacks the DC-9's signature "eyebrow" windows over the cockpit. But it is unmistakably kin to the popular 1960s-era short-haul airliner that brought the Jet Age to so many small and medium-size communities. Douglas delivered 976 DC-9s, not counting the MD-80 stretch versions.

Originally christened the MD-95 and renamed when Boeing bought McDonnell Douglas, the 717 combines the proven DC-9 airframe with quieter, fuel-efficient engines and significant upgrades in systems, avionics, and some interior and exterior materials and assemblies. In spite of its successful lineage, the 717 has not sold well; since its introduction in 1999, fewer than 200 have been bought or leased.

The airlines that operate it love it. Milwaukee-based Midwest Airlines flies 14 717s and has ordered another 11. David Reeve, Midwest's senior vice president of operations, says the airline's 717s burn at least 25 percent less fuel than the DC-9 and have an on-time-departure rate of better than 99 percent (as opposed to 97 percent for the DC-9s the airline previously operated). Passenger feedback on the aircraft has also been extremely positive, according to Reeve. The 717 has larger overhead bins and a significantly quieter cabin than the DC-9 and the MD-80.

Joe Leonard, chief executive officer of low-fare Air Tran Airlines, calls the 717 "a fantastic airplane." The airline's 50-airplane order launched the 717, and recently the profitable, fast-growing company ordered two more and took options for an additional four. But

BOEING HISTORICAL ARCHIVES

Long Beach workers built 4,285 C-47s during World War II and had a party at number 2,000 (left). Today there is less demand and more efficiency. Charles Perrin (below, left), a structure mechanic on the 717 (below), has worked at the Long Beach plant for 38 years.

last year, Air Tran also ordered 50 of the larger 737s and took options for 50 more of those.

Although many airlines have expressed interest in the 717, only Air Tran, Midwest, and Turkmenistan Airlines are awaiting deliveries. "The 717 suffers from the lack of commonality with other Boeing products," says Adam Pilarski, an analyst with Avitas, a Virginia-based aviation consulting firm. "If I can't fill my plane with 118 seats, for example, but I can fill one with 105 seats, it would be nice to substitute the smaller airplane on that route. Airlines are moving more and more toward families of aircraft so they can make those substitutions and save costs in crew training, maintenance, and spare parts.

"And airlines are not convinced of Boeing's commitment to the airplane," he continues. "Yes, they will honor orders, but if I operate this airplane, will there be siblings? Will there be improved versions of the project?"

In a filing earlier this year with the Securities and Exchange Commission, Boeing said that it might have to take a $400 million write-down on 717 production-related expenses. Some have interpreted this as one more sign that the 717 is doomed. Corporate accounting practice frequently spreads large expenses incurred in the development and marketing of products over the expected years of production, with a small percentage deducted from the revenue earned from the sale of each product. If the product line ends, the remaining costs must be shown on the books.

Ironically, Boeing has with the 717 instituted a method of assembly that has smoothed the production kinks that periodically stalled deliveries at Long Beach. The method is called the "moving line."

CHAD SLATTERY

In the million-square-foot building east of Lakewood Boulevard where 2,000 DC-9s and MD-80s and -90s were built, Boeing dug a trench 1,000 feet long, 25 feet wide, and three feet deep in the middle of the production floor. In the trench is a chain that continuously pulls 717s on skates at a rate of one half inch per minute. "The movement is so subtle that it's almost imperceptible," says Bill Wasserzieher. "It's a nice smooth operation that turns out a great little airplane."

The unvarying pace guides the workflow for the 300 assembly mechanics and 120 support personnel who build the airplane. Electrical and air lines are attached to the skates so they don't have to be dragged across the shop floor.

Structure mechanic Charles Perrin, who now works on the 717, remembers the assembly of McDonnell Douglas airplanes: "We used to have a line move day and that's all we did all day is move the airplanes," he says. With the 717's moving line, "we don't even have to move the heavy [towing] equipment in."

Perrin, whose team had reduced by

a thousand hours the time spent building the MD-90's horizontal tail section, had hoped to make the same structure for the 717. "The MD-90 has the same horizontal as the 717," he says. "We put a bid in, but they sent it out to be done overseas."

Very little of the 717 is actually fabricated in Long Beach: The fuselage barrels come from Alenia in Italy, the nose section from the Aerospace Division of Korean Airlines in South Korea, the empennage from AIDC in Taiwan, the landing gear from Israel's IAI, the cabin furnishings from Fischer in Germany, the avionics, wheels and brakes from Honeywell in the United States, and electrical assemblies from Labinal in France.

When I walked through the 717 assembly building last summer, I was struck by how quiet it was. It felt more like a spacecraft clean room than a traditional aircraft assembly plant. The only sounds were the noise of compressed air tools and the music wafting from mechanics' boom boxes: smooth jazz. Decades of seniority-based layoffs have left Boeing with a production floor where the average age is 54. Local 148 president Bill Schultz estimates that up to 200 union members will retire this year.

Partly because of uncertainties over the 717's long-term future, a union vote held last May returned an unusual result. Against the advice of their leadership, UAW Local 148 members ratified a three-year contract with Boeing. The contract contained modest cash bonuses and wage increases. It imposed significant increases in employee contributions for health insurance. However, perhaps shrewdly, it also offered a staggering 20 percent increase in pension benefits for new retirees.

"We have a retirement almost every week now," observes Charles Perrin. "You come into work every day and see all these buildings coming down," he continues. "The place is just melting away, and it's sad. It's not all Boeing's fault. I don't know who to blame."

The demolition along Lakewood Boulevard is almost complete. When Douglas Park is built where the Douglas factory once stood, Long Beach will have 3.3 million more square feet of commercial and office space, up to 200,000 more square feet of retail space, 1,400 more residential units, 400 more hotel rooms, and over 11 more acres of public parks. Still, for the employees who send airliners out the door, it's difficult to comprehend that the most valuable asset of this once sprawling aircraft complex is now the earth beneath it.

CHAD SLATTERY

The 717 is the last airliner to be built at Long Beach, where Douglas, McDonnell Douglas, and Boeing have manufactured thousands of airplanes.

BOEING HISTORICAL ARCHIVES

How Things Work:

Hush Kits

by Roger A. Mola | Illustration by John MacNeill

In 1969, in response to complaints about airport noise, the Federal Aviation Administration began restricting aircraft noise levels near runways.

The new Federal Aviation Regulation Part 36 measured noise at various locations: beneath the approach path; at the takeoff or go-around point; and next to the runway centerline, at the point where engines are typically at full power. For older and heavier aircraft, the rule set noise levels based on their age and maximum takeoff weight. And the signatory nations of the International Civil Aviation Organization agreed that as engine technology improved, they would impose tighter standards.

For civil air transports, standards are now at Stage 3, which says airlines may buy new aircraft that meet Stage 3 requirements or replace the Stage 2 engines with quieter ones. Until a recent action by the European Union, airlines could also modify the old engine with a device called a hush kit. Stage 4 takes effect after January 2006, mandating aircraft that are quieter by another 10 EPNLdB—effective perceived noise level in decibels, a unit based on a complex formula.

In the United States, the FAA has defined aircraft noise as "significant" if its average hourly level, day and night, tops 65 dB or, more precisely, 65 dB DNL (day/night noise level, also sometimes stated as LDN). At each airport, microphones sample the noise and record it continually. Airports have DNL contour maps (see below) that indicate the areas subjected to a day-long hourly average of 65 dB or above, usually measured over a year's time. A 10-dB penalty is added to noise measured between 10 p.m. and 7 a.m.

Controversy surrounds not only noise standards but also noise measurement technologies. Tests are hard to duplicate with precision, and placing a microphone on concrete versus grass, or at varying distances, yields different contours. Those who count decibels, or sound quantity, are at odds with those who find sounds of certain qualities—a shrill whine, say—irritants even at a lower intensity.

Few older aircraft can meet Stage 3 standards, but for airlines in developing countries and for freight operators, old aircraft are more affordable, and to meet the noise issue, the answer is often hush kits.

Most hush kits address the process by which high-velocity hot jet exhaust clashes with cooler ambient air, generating the thunderous roar associated with jets. Slowing that exhaust, or spreading out the area in which the rumble takes place, is the goal. Sound-absorbing materials similar in function to acoustic ceiling tile enclose not only the exhaust but also the engine fan and intake cowl to reduce the noise projected forward.

Some kits replace the round exhaust nozzle with a fluted shape like that of a bundt cake pan. The increased surface area diffuses and calms the stream of exhaust. Adding exhaust pipes can lower the speed of each stream; lengthening the exhaust duct reduces the velocity out the back end. Some kits tackle the exhaust farther forward in the engine, injecting ambient air . Each of these methods slows the airflow, reduces effective thrust, adds weight, and increases fuel consumption.

A new design, the chevron, consists of cutouts around the nozzle that create vortices in the exhaust flow. Developed by General Electric and refined at NASA's Glenn Research Center in Cleveland, Ohio, chevrons resemble shark's teeth, set randomly and capped like mushrooms, to hasten mixing of streams of ambient air,

COURTESY PORT OF OAKLAND

The outer yellow lines depict sound levels of 65 dB (average) around two runway complexes at Oakland, California. Heavy jets can't use the north runways. The decibel scale is logarithmic, so a 10-dB reduction sounds half as loud. The threshold of discomfort is 120 dB.

fan flow, and the engine's core.

Pilots can also reduce noise by applying noise abatement procedures: raising or re-directing their approach paths, climbing rapidly, or reducing power near airports. Though engine noise predominates, airflow around the wings, slats, flaps, and landing gear contributes its share. In 1997, James Raisbeck, a former Boeing engineer, offered what some called "the non-hush-kit hush kit" for the Boeing 727-200. It reduces the angle of deflection of the wings' leading edge slats, increases lift, and enables takeoff with reduced power and less noise.

After September 11, 2001, many older aircraft, possible candidates for hush kits, were hustled off to retirement. Yet by the end of 2003, FedEx, the largest operator of Boeing 727s, held orders from 60 airlines for 740 Stage 3 kits it designed in-house. Jet Engineering and Goodrich have since released a Stage 4 hush kit for some 300 MD-80s flying in Europe, though freight carriers with night operations, including UPS, are replacing engines or buying new aircraft. In 1999, the European Union published Regulation 925, effectively freezing the number of hushkit-equipped transports in its airspace. The rule would, at a stroke, reduce the value of unsold hush kits, which are primarily U.S.-made, to scrap. Because hush kits have added weight and limited performance, the EU aimed to "improve the situation regarding fuel burn and gaseous emissions."

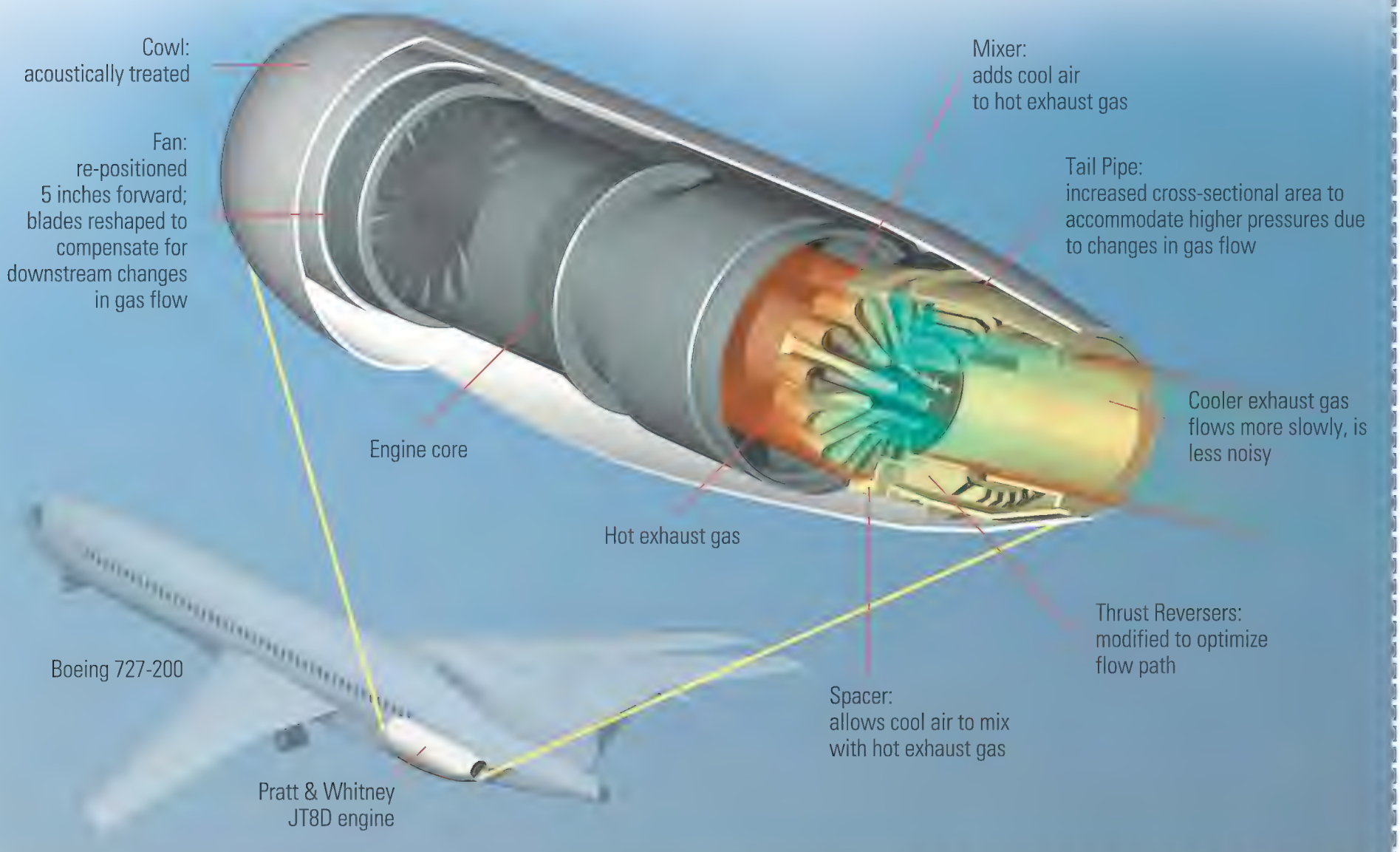
Europe also required that new foreign transports traversing European airspace have, instead of hush kits, high-bypass-ratio engines. Such engines make less noise per pound of thrust than one with a lower bypass ratio, though not necessarily less noise than one with a hush kit. U.S. representatives protested this requirement, which avoided mentioning U.S. carriers while carefully wording the rule so that U.S. aircraft equipped with hush kits were barred.

In September 1999, the U.S. House of Representatives determined that if the EU persisted, House bill H.R. 661 would ban the European Concorde from U.S. airports. Congressman Vernon J. Ehlers (R-Mich.) went even further before the Subcommittee on Aviation: "The [Airbus] A320 has a very annoying noise.... It would not be at all hard to disqualify the A320 from serving the United States...."

After two years of this, the EU decided to focus on older Russian aircraft, like the Ilyushin Il-76, a cargo carrier used in global relief efforts. In retaliation, Russia threatened to cut off access by European airlines and relief flights by the Il-76.

In the future, noise abatement procedures will be even more important than hardware, so air crew training will still be a key to success.

The FAA, in a December 2003 report on its own performance, said that between 1975 and 2000, the number of people exposed to significant noise had dropped 90 percent, adding that industry may have done all it can with hush kits and technology; future gains may require residential soundproofing or relocation.



The Things That Fell to EARTH

How NASA can predict when space junk will fall in your back yard.

by James E. Oberg

GEORGE GONGORA/CALLER-TIMES

NASA

NASA

Nicholas Johnson (wearing tie) interviews Barney Corey about an Ariane 5 nose cone found on a Texas beach. Corey dug a hole behind his mobile home, intending to use his find as a hot tub, but the cone was returned to its owners in France. In 1997, a fuel tank from a Delta II launcher landed in Texas (left). Four years later, a titanium motor casing from another Delta II ended up in Saudi Arabia.

On January 15, 1995, a Japanese rocket took off from Kagoshima, carrying a Russian-made satellite with German scientific instruments. The mission's purpose was to test materials processing techniques in microgravity and then return the samples to a landing zone in Australia.

But the launch vehicle swerved off course and headed for the horizon. Ground controllers in Germany listened for radio signals indicating that the satellite had reached a stable orbit, but they heard nothing. Without such confirmation, they eventually concluded it had fallen back to Earth. Searching for the satellite was never considered since it could have ended up almost anywhere, and all involved with the mission assumed that the Russian spacecraft would never be seen again.

As it turned out, the heat-shielded landing capsule ended up in northern Ghana, near the town of Tamale, after the satellite had limped around Earth twice in a lopsided orbit. The capsule's parachute had opened as planned, and as the craft drifted down, it broadcast homing signals that nobody picked up.

Villagers outside of Tamale witnessed the landing and called the local schoolmaster. It was obvious to him that the vehicle was a spacecraft and, given the Cyrillic characters on its side, probably of Russian origin. The schoolmaster organized a recovery team, who trucked the hardware to a storage room in town. Then he wrote to officials in Accra asking how to contact the satellite's owners.

Months later, news of the space object reached Geoffrey Perry, an amateur satellite tracker in England, who quickly realized it must be the lost Russian vehicle. He knew whom to call in the German space program, and a few months later, staffers from the German embassy in Ghana showed up in Tamale and asked for their payload. Along with the capsule, the Germans were given a bill for the storage fee, which they grudgingly paid.

Had the Germans known the capsule's point of reentry into the atmosphere, they could have avoided the storage fee. Eight years later, another team desperately seeking another failed space vehicle knew its point of reentry. Using models that can predict how space objects fall through

ARNOLD ENGINEERING DEVELOPMENT CENTER

Aerodynamicists tumbled a scale model of the space shuttle's external tank to simulate the stress of reentry.

Earth's atmosphere, this team was able to pinpoint not merely the continent, the country, and even the county where something had fallen, but the likely pasture.

For weeks, searchers on foot had combed the ground in east Texas, seeking pieces of the space shuttle *Columbia*, which on February 1, 2003, had broken apart during reentry, killing all seven astronauts aboard. The location of each fragment of the shattered shuttle was carefully documented, and then the parts were transported to a hangar at Kennedy Space Center in Florida, where reconstruction efforts tried to help forensic engineers discover what had gone so terribly wrong.

On March 18, a recovery team was sent to an area that had already been searched; in fact, it had been marked "completed." This time, though, the team was seeking one particular piece of hardware that had been aboard *Columbia*. Knowing its size and weight, and the distribution of other pieces already recovered, experts in reentry dynamics had concluded that the 58-pound object—a VCR-size box containing potentially valuable flight data on the doomed mission—would lie in the already-searched area.

Sure enough, on a hillside near Hemphill, Texas, technicians found the Orbiter Experiment Recorder, embedded several inches in the ground. It contained time-tagged measurements that were exactly what investigation teams needed to pinpoint the moment *Columbia*'s left wing had collapsed, an event that preceded the breakup of the vehicle.

The insights that led to the search team's discovery had been developed over many years of study at NASA's Johnson Space Center in Houston, Texas, and an earlier instance of spacecraft disintegration made the shuttle searchers confident that they were on the right track.

While out walking her dog with friends before sunrise on January 22, 1997, a woman in Tulsa, Oklahoma, was hit by a man-made object that fell out of the sky. Half an hour before, Lottie Williams had watched an impressive fireball

The U.S. Air Force runs an observatory in Hawaii that can track orbital debris.

FRANK RIZZO/ USAF

streaking through the sky from north to south. "I noticed in the sky there was this big bright light, like a fire," she told a reporter from the *Tulsa World* newspaper. "I turned to my friends to say look, and when I turned back it was coming towards us." Then two sparks shot from the fireball and disappeared over a building.

Later, when a slowly falling piece of charred woven material brushed Williams' left shoulder and hit the ground "with a metallic sound," she concluded that there was a connection between the two events, especially since the next day's news was full of stories about "space junk" found on the ground in Texas. A large stainless steel fuel tank, which bore evidence of surface melting, had landed in the front yard of a farmer near Georgetown, Texas, partially collapsing on impact. And outside the town of Seguin, a titanium pressurant sphere, undamaged except for some discoloration, had embedded itself halfway into a field.

Nicholas Johnson, chief scientist of the Orbital Debris Program Office at Johnson Space Center, soon got word of the discovered space debris. A few days later, he made the drive from Houston to Georgetown, where he identified the tank as having come from the one-ton second stage of a Delta II rocket booster. The U.S. Space Command in Colorado Springs, Colorado, had been tracking the Delta II for several days. Nine months earlier, it had launched a U.S. Department of Defense payload. After the rocket stage's orbit finally decayed, it had reentered the atmosphere around 3:30 a.m. over the south-central part of the country. The reentry was seen by observers in Texas, Kansas, Missouri, and Arkansas.

The collected orbital debris was shipped to the Johnson Space Center. The fuel tank and the pressurant sphere found in central Texas were obviously from the fireball. But investigators initially doubted that the piece of metal mesh that had fallen on Lottie Williams was from the rocket, since it had been recovered so far upstream of the bulk of the Delta II's debris.

At the Orbital Debris Program Office, Johnson is in charge of NASA's efforts to predict what sorts of space junk can be expected to reach the ground after the natural decay of objects' orbits. Despite the fact that hundreds of fragments of space objects have been found around the world and sent to various government agencies, conventional wisdom is that entering objects burn up. "Some launch companies until recently claimed in commercial launch license applications that spent stages totally burn up in the atmosphere," says Johnson. When the Russians remotely command the supply vehicles that service the space station to reenter the atmosphere, they claim that the vehicles "cease to exist," yet they choose to dump them over the far southern Pacific rather than over Russia—just in case.

According to William Ailor, director of the Center for Orbital and Reentry Debris Studies, between 100 and 200 large (bigger than a breadbox) man-made objects reenter each year. In 1999, Ailor has estimated, for example, that 212 tons of hardware hit the atmosphere, and a quarter of it, about 42 tons, probably reached the surface. And during the first 40 years of the Space Age, Ailor estimates that as much as 1,400 tons of man-made material has reached the

TULSA WORLD

On January 22, 1997, Lottie Williams was grazed by a slowly falling piece of mesh.

surface of Earth. He says, though, that worldwide, only about 250 discoveries of authentic spacecraft pieces have been reported because most pieces have landed in water.

For years, researchers had no reliable numerical models to predict which pieces of a space vehicle would survive entry and reach the ground intact. Estimates were made "by guess and by golly," says Johnson. But in the 1990s ITT Systems in Alexandria, Virginia, developed a numerical model that took all known thermal processes into account in order to predict the fate of entering objects. Around the same time, a team of engineers from NASA and Lockheed Martin worked jointly to create a numerical model called Object Reentry Survival Analysis Tool (ORSAT).

Johnson and his team at NASA have found the ORSAT program particularly helpful in understanding what happens to an object after the stress of deceleration causes it to disintegrate. Once a satellite breaks up, for example, and its individual components—often in the form of spheres,

cylinders, and plates—are streaking in on their own, the reentries of the basic shapes are much easier to predict than those of the irregular shapes common to most intact satellites. "Tumbling titanium spheres survive reentry totally intact," says Johnson. Further, components with protuberances are affected by aerodynamic drag differently than smooth components, with the protruding parts forming a "tail," so that the front end of the object gets really roasted (some of NASA's reports contain photographs of recovered spheres with burn holes opposite the protuberances).

Johnson's group has applied the ORSAT model to known entry events, including the reentry and breakup of the nuclear-powered Russian satellite Kosmos 954, which rained radioactive debris over Canada on January 24, 1978. As the ORSAT model predicted, Kosmos 954's beryllium fuel rods became very hot during reentry. But the rods survived because they were made of beryllium. "This is because of the extremely high heat of fusion of beryllium," says Johnson. Steel and metals such as titanium and nickel share beryllium's ability to handle the heat, while aluminum and copper objects usually vaporize soon after breakup.

Johnson is particularly proud of the ORSAT model's results for debris from the Delta II rocket stage that reentered over Texas in January 1997. Using data such as size, weight, and composition for the fuel tank, pressurant sphere, and rocket nozzle, the ORSAT model indicated that all three pieces would survive reentry, which they did. Additionally, the ORSAT program's prediction of the landing sites for all three pieces matched well with the actual locations.

Unlike the fuel tank and the pressurant sphere, the Delta II's rocket nozzle is made of the metal columbium, which is mechanically weak but can withstand high temperatures. The ORSAT model showed the rocket nozzle being heated quickly, then cooling quickly and eventually falling to the ground at a speed of about 33 feet a second (compared to the impact speed of the heavier tanks, 260 feet a second). As the nozzle approached the ground, it was already at air temperature. "Our research has shown that the material does survive reentry," wrote Johnson in a NASA report, "and that it 'floats' down, landing approximately 30 minutes after the steel tank impact and 500–600 kilometers uprange."

What about the piece of mesh that hit Lottie Williams: Had it also been shed from a Delta II? Williams has never loaned the object to NASA, but she did send a fragment to the Center for Orbital and Reentry Debris Studies, which concluded that its composition is consistent with Delta II insulation. Because the mesh has no identifying marks or numbers, though, it cannot be proven to have come from a particular rocket. Still, the "circumstantial evidence is highly convincing," says Johnson, who points out that the mesh's location and time of landing are consistent with the 1997 Delta II reentry.

When an object reenters the atmosphere and breaks up, the debris is scattered along a field, or footprint, with lighter fragments landing near the "heel" of the footprint and heavier objects traveling farther downrange toward the "toe"; this explains why Williams' mesh floated down in Oklahoma, far uprange of the heavier pieces that plowed into Texas. The ballistics characteristics of the heavy pieces also ensure that they'll travel at a higher velocity—and reach the ground sooner—than the lighter pieces.

Lottie Williams wasn't happy with these results, however. "I was thinking I had something celestial," she told the *Tulsa World* reporter. "And here I got something man-made."

The ORSAT model can accurately predict entry heat loads on falling objects because it factors in the actual processes at work. In contrast, the idea that air friction is the cause of reentry heat is persistent but misleading.

AP/WIDE WORLD PHOTOS

Authorities in northwestern Canada had the unpleasant task of gathering radioactive debris from Kosmos 954, a Soviet nuclear-powered satellite that broke apart during reentry on January 24, 1978.

Atmospheric entry heating of man-made objects was first noted in 1944, when Nazi Germany's V-2 rocket warheads hit the atmosphere over London at about 6,000 mph. As they reentered, compression-induced shock waves heated the air ahead of the plunging warheads enough to prematurely detonate the explosives inside. German engineers solved the problem by lining the warheads with plywood to serve as a heat shield.

But after the Bell X-1 rocketplane made its sound-barrier-breaking flight on October 14, 1947, confusion began to set in about atmospheric heating. The X-1 and other high-speed aircraft, such as the North American X-15, which first flew in 1959, faced severe thermal environments. Supersonic air rubbing across the aircraft's outer skins created frictional heating, which had to be endured or actively cooled. And from then on, the notion of atmospheric heating was indelibly linked with air friction in media explanations and thus in the public mind.

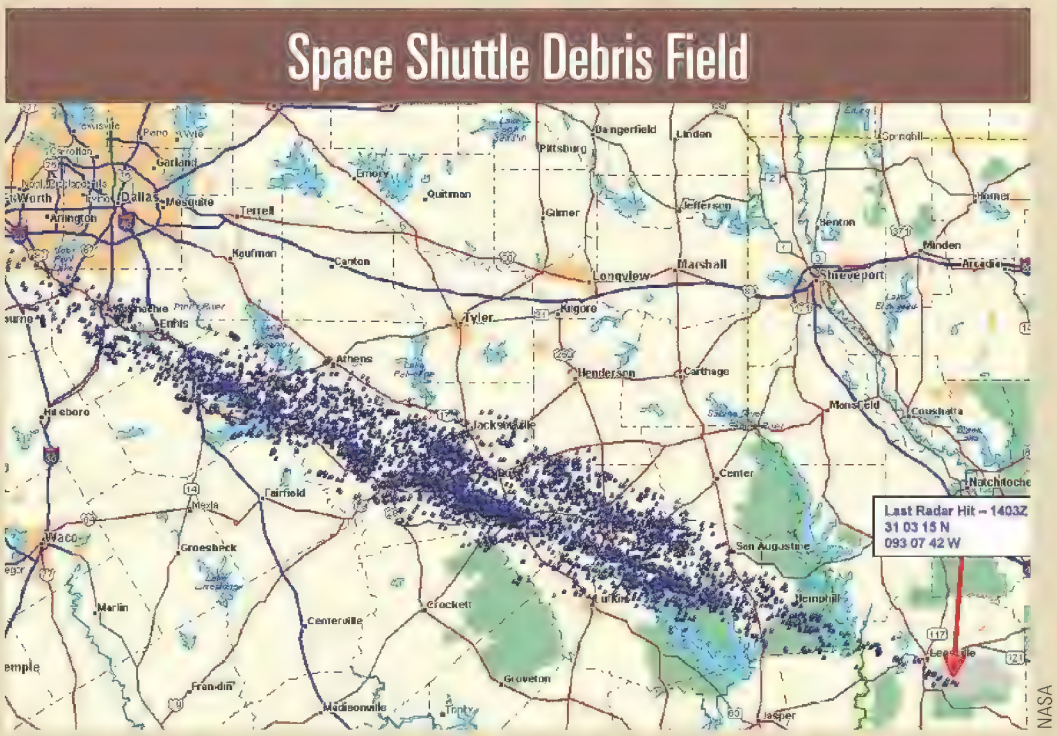
But air friction has little to do with the process that heats objects entering Earth's atmosphere. The key source of the heating is compression: Air molecules in front of an incoming object can't move out of the way fast enough, so they pile up, or compress, which makes them very hot. The air molecules get "aggravated," as the late Max Faget liked to say when he explained how he invented the heat shield

for the spacecraft of NASA's Mercury manned space program. Or as space engineer Jim Davis says: "This is due to the spacecraft performing work on the atmosphere like a piston in a cylinder."

The air molecules caught up in the shock wave created by the incoming object can heat up to 11,000 degrees Fahrenheit, as hot as the surface of the sun. This heat reaches the reentering object mainly by conduction, as the superheated air molecules repeatedly strike its surface. At higher reentry speeds—say, when the U.S. Apollo manned space capsules returned from the moon at 25,000 mph—the compression-induced shock wave becomes so hot that it transfers much of its heat into the reentering object through direct thermal radiation. And at the speeds at which meteors hit Earth's atmosphere, up to 150,000 mph, nearly all of the heat transfer is through radiation.

NASA

Just as computer models of reentry dynamics predicted, after Columbia *broke apart, its flight data recorder (left) came down on a hillside in the eastern Texas town of Hemphill.*



NASA

U.S. Forest Service workers (right) found the bulk of debris from Columbia *lying along a 260-mile swath beginning near Fort Worth, Texas, and extending across the border into Louisiana.*

Understanding how objects break up and scatter in the atmosphere is a relatively new science for NASA, but one with a wide range of applications. During space shuttle launches, for example, the external fuel tank, which weighs 44 tons empty, hits the atmosphere an hour or so after launch and breaks apart, with metal fragments scattering along a footprint in the Atlantic Ocean. Mission planners must place the entire footprint in a region that sees little commercial sea and air traffic, and for some launches, planners had difficulty finding a big enough dumping ground. But then a Lockheed Martin computer analysis showed that the external tank was breaking up at a substantially lower altitude than first estimated and the pieces were scattering over a correspondingly smaller area. Once the computer prediction was confirmed by direct observation, shuttle mission planners had more leeway in calculating where the remnants of the tank could plunge.

Knowing what kinds of materials and structures are likely to survive entry and reach Earth intact also enables NASA to calculate more reliable probabilities of property damage and personal injury. In 2001, such calculations ended the mission of the Compton Gamma Ray Observatory when it was shown that the satellite's heavy structural materials presented a greater than 1-in-10,000 chance of harming property and people. The satellite had a gimpy control system, so instead of waiting for it to fail and leave ground controllers with no means of directing the craft's reentry, mission control dumped the satellite into the far southern Pacific Ocean while it was still controllable.

Following the 2003 *Columbia* disaster, the Center for Orbital and Reentry Debris Studies became involved in assessing the scatter pattern of fragments from the shuttle. On March 17, coincidentally just a day before *Columbia*'s flight data recorder was recovered, CORDS director William Ailor testified before a public hearing of the *Columbia* Accident Investigation Board in Houston. Because the *Columbia* accident investigators needed to know whether the damage they saw on recovered fragments resulted from events that happened earlier in the shuttle's flight (and that may have led to the disaster) or from the stresses endured during reentry, they were interested in learning how different materials react to entering Earth's atmosphere. The *Columbia* accident investigators also wanted a way to judge how thorough their search was by comparing the weight of recovered *Columbia* material to calculations of how much should have reached the ground.

NASA

"For unprotected space hardware, the heating and loads will gradually tear it apart," Ailor explained to the investigators during the hearing. "The kinds of things that we've seen that survive reentry are things that you would probably guess might—things like steel sometimes, glass, titanium, and then parts that are sheltered by other parts. One

KSC/NASA

Forty percent of Columbia *has been found and shipped to Kennedy Space Center in Florida, where engineers reconstructed the remains in an attempt to understand the shuttle's fate.*

of the things about the reentry breakup process is that the heating is like, in a sense, cooking an onion. You basically start from the outside, and then as you heat the pieces up to a point where the materials will fail, that will expose some new materials. They'll go through the same process and the object can be broken apart. We do have objects that are melted and shedded away, things like aluminum [and] solar panels.

"For example, when an object comes off of a parent body, it now experiences the air stream that exists there, and it will respond based on its own characteristics. If you've got a very lightweight piece that comes off of a heavier object that's coming through the atmosphere, it's like throwing a piece of paper out of a car. That will decelerate very quickly, and the same things happen even at Mach 20."

Ailor went on to explain how timing and release conditions can affect survivability, both of particular significance in the hunt for *Columbia* debris. "If an object comes out late in the reentry, after being shielded for a portion of the reentry, that means a lot of the energy has been taken out of that trajectory prior to that object's release, and that object is more likely to survive," he said. This shielding effect explains why *Columbia* searchers found documents, videotape, cloth patches, and astronaut remains among the items that made it to the ground.

Ailor estimated that anywhere from 10 to 40 percent of a space object would actually survive reentry. The odds of its being found, however, are much lower, even with the models that CORDS has developed.

Careful study of the debris field from the *Columbia* accident helped improve the odds of success in that search. As truckload after truckload of debris was gathered, NASA engineers began to hope they could find particular pieces. "We did analyze some specific components," says Nicholas Johnson. "Most already had been found, and we were asked to go back and use our models to look at those locations. We had very close agreement."

Insights from such computer simulations and a reconstruction of the moments of *Columbia*'s breakup enabled accident investigators to take the next step. With the Orbiter Experiment Recorder still missing, but with pieces known to have been installed near it found, the region where it ought to have fallen was carefully plotted, leading to its recovery and its use to solve the more heartbreaking mystery of what destroyed the space shuttle.

Smithsonian
National Air and Space Museum

— Jon Reynolds, Brigadier General, USAF (Ret.) in front of one of his favorite planes in the Smithsonian collection, the F-100D Super Sabre. The aircraft is presently kept at the Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Maryland.

PHOTO: ERIC LONG

"All these aircraft set every milestone in aerospace history..."

"Thirty-one years in the Air Force gave me many great opportunities. I flew several memorable aircraft including the F-100, the F-105, and even a MiG-17 when I was stationed in China as Defense Attaché."

His first opportunity was at age 12, when Jon Reynolds flew in a float plane off a lake in Canada. Hooked on flying, he went on to an extraordinary career. He's a pilot with two combat tours in Vietnam, a retired Air Force Brigadier General, a professor with a Ph.D. in history who taught at the Air Force Academy, and a Board member of the National Air and Space Museum.

Jon Reynolds and his wife, Emilee, have also taken the opportunity to make the National Air and Space Museum beneficiary of a generous trust. They are now members of the *Smithsonian Legacy Society.*

Find out how you can include the National Air and Space Museum in your estate plans. Fill out and return the reply form below, or call 202-633-2602. You may also e-mail legacy@nasm.si.edu. Additional information can be found at **www.nasm.gift-planning.org**. Continue the opportunity for everyone!

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A&S 01-05

The aerobatic team Lima Lima relies on its half-dozen T-34s to fire up crowds at airshows year-round.

SAVE THE MENTOR!

When wing failures grounded the T-34, Mentor owners sought their own fixes. **BY PETER GARRISON**

The mock dogfight, on April 19, 1999, began with the airplanes outside each other's visual range. When the pilots caught sight of each other— both flying Beech T-34 Mentors in gray and blue U.S. Air Force camouflage paint, with "SW" in big black letters on their tails—the one at "perch" (the higher altitude) began a descending turn to intercept the aircraft below it.

In the rear seat of the attacking airplane was Dan Bouck, 51, of Atlanta, an airline pilot with 15,500 hours of flight time. Bouck, the safety pilot, had been flying for the Sky Warriors civilian aerial combat school for two years and had logged 450 hours in the T-34. In the front seat was the customer, another professional pilot, Ted McFann Sr., 60, who had retired from the airlines with some 25,000 hours.

Bouck urged McFann not to be shy as he closed on the other airplane. "Roll all the way through—harder, harder! All the way through! That's it, that's right. Bury your nose, bring it down. That's it, good! Now don't chase him into the ground."

Without warning, as the T-34 made a tight left turn, its right wing separated near the fuselage. The aircraft whirled out of control. Both pilots were wearing parachutes, but as the wing failed it swung over and crushed the canopy. Both men died in the crash, which also destroyed a half-century of confidence in the structural integrity of the T-34.

The T-34 Mentor is a military trainer version of Beech's tremendously successful Bonanza, the V-tail four-seat airplane that came onto the market in 1947. For the trainer, Beech replaced the Bonanza's cabin and upper fuselage with a greenhouse-style canopy, similar to that on the World War II North American T-6 Texan trainer. Tandem seating put the student in front, instructor behind. The original engine was a six-cylinder, 225-horsepower Continental O-470. A conventional three-surface empennage replaced the Bonanza's trademark V tail, which had been intended to produce less drag but never quite provided solid yaw stability.

The Bonanza had originally been certified in the "utility" category, with a load limit of 4.4 Gs. Airplanes used for aerobatics—and those used by military pilots—must be sturdier. Their structures must be able to withstand plus 6 and minus 3 Gs without permanent deformation. They must withstand 9 Gs or minus 4.5 Gs without breaking, though the structure may be permanently bent. These are the limits the Mentor was certified to withstand. (With minor reinforcements, the Bonanza also proved capable of handling the higher aerobatic loads.)

The U.S. Air Force bought 348 T-34As, with deliveries beginning in 1953. A year later the Navy ordered a slightly modified version, the T-34B; Beech eventually delivered 423. A few foreign air forces also bought the airplane, and some were assembled under license in Japan, Canada, and Argentina. Production of the piston-engine versions ended in 1959, but Beech delivered 441 copies of a turbine version, the T-34C (or "Charlie"), to the Navy between 1976 and 1990. The 300-mph Charlie, powered by a 400-horsepower Pratt & Whitney turboprop, is 1,000 pounds heavier than the A and B models, and uses a stronger main wing spar, adapted from Beech's twin-engine Duke.

Mentors began to filter into the civil registry during the 1970s as the Air Force and Navy released airplanes to the Civil Air Patrol, foreign air forces started to retire them, and enterprising shops began assembling airplanes out of scrapped parts. (Charlies have not yet trickled down into civil hands, though many T-34 aficionados would sacrifice minor body parts or close relatives to get one.) Owners often paint them in military camouflage or in fanciful schemes mingling inspirations from several military liveries. Many T-34s have received newer, more powerful engines of 260 or 285 hp.

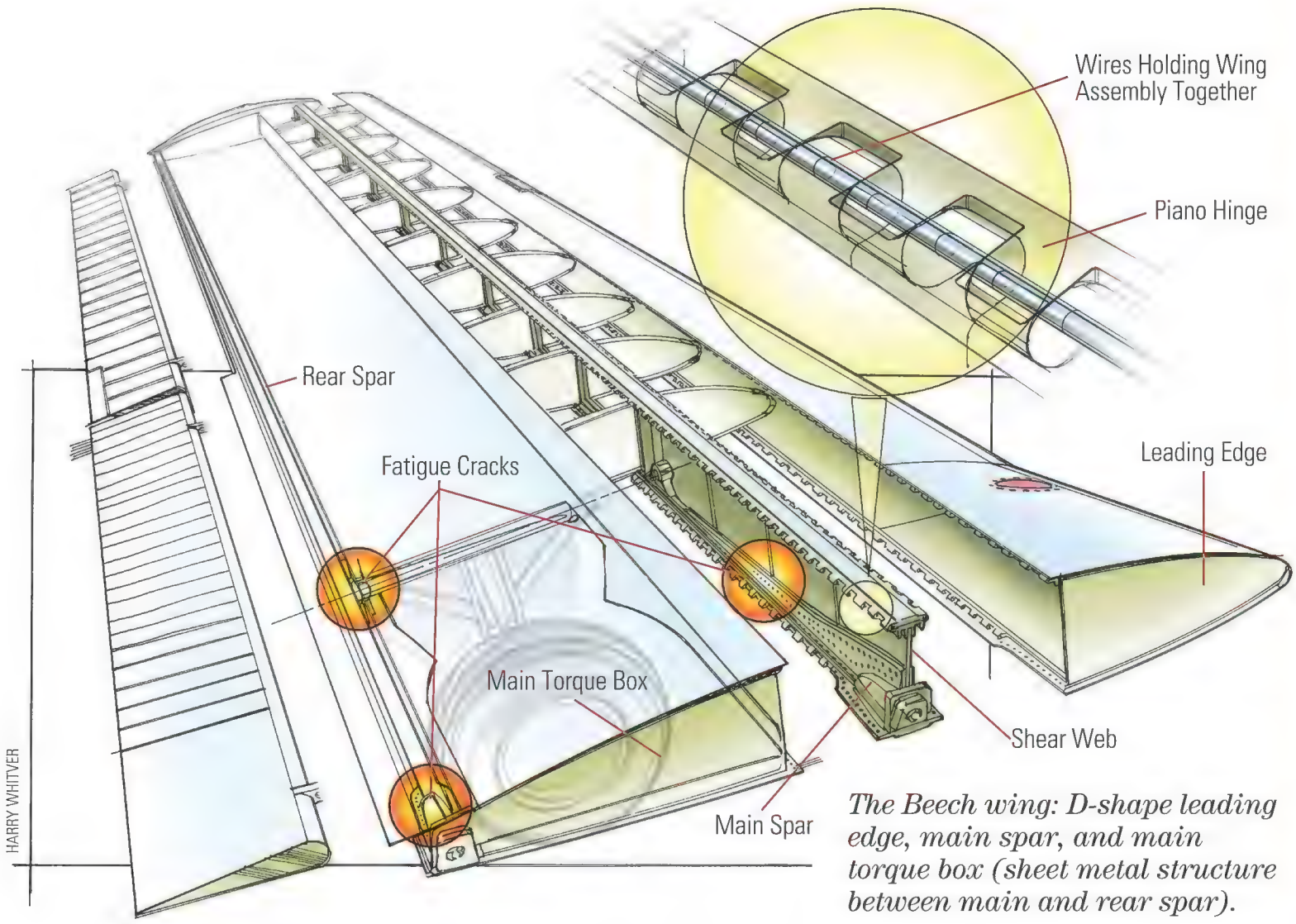
Eventually, the civil fleet grew to nearly 500.Owners banded together in a T-34 Association, which organizes fly-ins and formation flights and publishes a quarterly magazine. A six-plane T-34 acrobatic team, Lima Lima, maintains a year-round schedule of performances, as does T-34 airshow performer Julie Clark.

Inflight structural failures are rare events. Usually they occur when a pilot loses control in clouds, emerges in a spin, and, in a desperate effort to recover, overstresses the airplane. Occasionally, an airplane is torn apart by turbulence in a thunderstorm. But the Sky Warriors accident was obviously in a different category.

National Transportation Safety Board and Federal Aviation Administration accident investigators found that the main beam, or spar, of the Sky Warriors airplane's wing had failed about a foot outboard of the fuselage. If the spar had failed from simple overstress, investigators would have concluded that McFann had pulled too hard, and that would have been that. Instead, they found that the fracture surface showed clear signs of metal fatigue. A crack had been developing in the spar for some time before the accident. Detailed examination of the entire wreckage uncovered fatigue cracking in the lower rear attachment fitting of the rear spar as well.

"Metal fatigue goes on continually in aluminum airplanes," says aeronautical engineer George Braly, a partner in General Aviation Modifications, Inc., an Ada, Oklahoma developer of equipment to improve the performance of general aviation engines (see "First Church of Combustion," June/July 2004). As co-owner, with business partner Tim Roehl, of a T-34, Braly has a personal interest in the airplane's fate.

OPPOSITE: LESLIE HICKS



The Beech wing: D-shape leading edge, main spar, and main torque box (sheet metal structure between main and rear spar).

Contrary to what many pilots believe, it's not only intermittent high loading that fatigues metal; it's any flexing due to changes in loading, even the small changes that turbulence causes during routine cruising flight. Given enough time in service, all aluminum wings will eventually fail from fatigue, but airplane structures are designed to support many tens of thousands of hours of flexing.

"The amount of fatigue that occurs," Braly says, "depends both on the [magnitude of] stresses the structure experiences and on the number of times they occur." In other words, thousands of hours of cross-country cruising will fatigue a structure as much as repeated high-G loadings occurring a few times a day. Unfortunately, fatigued material looks the same as new material, until it's far enough gone for cracks to appear.

Evidence of fatigue cracking in even a single airplane raises a red flag with the FAA. If one airplane has cracks, it's likely that others of that type do as well. Within a month of the Sky Warriors accident, the FAA issued an emergency Airworthiness Directive, or AD, temporarily limiting all civil T-34s to 2.5 Gs positive and prohibiting them from exceeding 175 mph. The emergency action was not so drastic as some the FAA had taken, completely grounding Learjets in one case and Cessna 441 Conquests in another, but it was still a burden for airplanes that are widely used for aerobatics.

The FAA enlisted Raytheon Corporation, the parent of Beech Aircraft, to determine how best to ensure the future safety of the T-34 fleet. Raytheon spent almost two years on the problem while T-34 owners dangled in suspense. From the first, some owners darkly suspected that it was probably in Raytheon's interest, from the standpoint of limiting its liability exposure, to wipe out the whole fleet. Others, more charitable, thought that Raytheon's Beech engineers were as eager as anyone to keep the fine old airplanes flying, and that the length of time they spent coming up with a prescription was really intended to give beleaguered T-34 owners, who were faced with the possible reduction to junk-bond status of their $200,000 investments, a little breathing room.

Whatever Raytheon's motives may have been, the company's eventual response was draconian. According to an AD issued in August 2001, each T-34 front spar and rear spar attachment would have to be subjected to a magnetic eddy-current inspection for cracks every 80 flight hours. The inspections, which are relatively difficult to perform (and also prone to yield occasional false positive findings), would cost thousands of dollars, even after initial modifications had been performed to make the suspect areas more accessible. For a heavily used airplane, the 80-hour interval could mean two or three inspections a year. Nobody would want an airplane saddled with such demanding inspection requirements; in five years, says Lima Lima's Bill Cherwin, the requirement would "turn the whole fleet into beer cans."

Even before the FAA published the Raytheon inspection procedure, however, T-34 operators and their support organizations and businesses had begun to think about what the FAA calls alternative means of compliance. The FAA allows AMOCs as an avenue for independent solutions to engineering problems. Raytheon had not come up with a solution that T-34 owners could afford. If there was to be an affordable solution, owners would have to come up with it themselves.

In principle, two paths lay open. One would completely eliminate the suspect spar components, and therefore inspections for fatigue cracking. The other would perform one eddy-current inspection of the existing spar to ensure that it was free of cracks, and then strengthen it so as to preclude future fatigue failures.

MARK JOHNSTON

T-34s that lost wings had routinely flown in "unusual attitudes," like those in Julie Clark's aerobatic routine.

The simplest repair, the Saunders Strap, had been around for decades—the T-34 was not the first Beech airplane to have spar problems. The first was the pre-World War II Beech 18. When Model 18 spars got into trouble, Dave Saunders, a freelance engineer, stretched a stainless steel strap under the belly of the airplane from one outer wing panel to the other. The strap took over a share of the load being carried by the lower elements in the spar, which were the only ones subject to significant fatigue.

Other Beech aircraft—Queen Airs, King Airs, and Beech 99 Airliners—experienced fatigue cracking, and Saunders adapted his straps to all of them. When it became apparent that T-34s were going to need spar work, Saunders lost no time designing a strap for them; it is also suitable for Barons and Bonanzas.

The Saunders Strap costs only $12,000 installed, and the down time, assuming that the required eddy-current inspection doesn't turn up cracks in the spar, is only two to three weeks. While no one questions the structural effectiveness of the strap—no airplane equipped with one has ever suffered a wing failure—some T-34 owners object to the ridge it produces along the underside of the wing; purists don't like the idea of tacking a conspicuous structural Band-Aid to the outside. And, though Saunders denies it, some say that the strap saps performance.

Earle Parks' Amarillo, Texas shop is equipped to rebuild T-34s from any condition. In addition to a huge inventory of spare parts, Parks has enough tooling to build an entire airframe from scratch—if it were legal to do so.

Parks had his own ideas about the T-34 spar. He had seen enough disassembled T-34 wings to know that there was some random variation in the size and shape of the many small parts, some of them shims and spacers to bring larger members into alignment with one another. Beech had eliminated the buildup of small parts when it designed a new spar that it has installed in new Bonanzas and Barons since 1973, and Parks decided that he could do the same. He replaced the inboard section of the shear web—the thin vertical element of the I-shaped main spar—with a sheet of heavier stock, eliminating the joggled lap joint that coincided with the location of the fatigue failure in the Sky Warriors airplane. He replaced the complicated buildup of small parts in the lower spar cap—only the lower cap is subject to significant fatigue—with a single long part machined from a solid piece of aluminum.

Replacing a spar sounds like a huge job. In most wings, skins and ribs are riveted directly to the spar, so removing the spar entails drilling out nearly every rivet in the wing. The Beech wing, however, is an unusual design. It consists of three separate assemblies: the D-shape leading edge, the main spar, and the main torque box, a sheet metal structure between the main and rear spars. The three assemblies are neither riveted nor bolted together; instead, they are joined by stainless steel wires, about the thickness of a wire hanger, that run the full length of the wing through interlocking piano-style hinges. To separate the spar from the rest of the wing, all you do is pull out the wires. In building the first post-World War II high-performance personal airplane, Beech seems to have anticipated that periodic spar inspections might be needed someday.

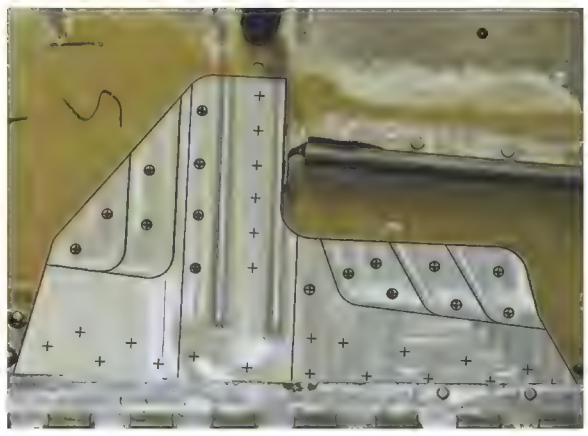
The FAA required that Parks perform a stress test to the 9 G ultimate load. Parks built a heavy steel fixture, put a wing into it, and pushed on the wing with a hydraulic ram. The steel fixture deformed, but the wing did

JIM KOEPNICK/EAA

Beech's wildly popular Bonanza was the direct forebear of the Mentor.

COURTESY RICHARD FLECK, CAMARILLO AIRCRAFT SERVICE

Some owners were appalled by the appearance of the Saunders strap, likening it to a structural Band-Aid.



COURTESY LUKE KERR/GAMI

GAMI found the area of greatest stress and bridged it with a gusset.

COURTESY PETER GARRISON

Earle Parks assembles and rivets replacement spars in steel fixtures.

not. Parks got his Supplemental Type Certificate.

The most technically economical response to the spar situation emerged from GAMI, George Braly and Tim Roehl's company. GAMI first did a computer survey of the T-34 spar, using the now-universal method called finite element analysis, and found a hot spot of concentrated stress at the exact point where the Sky Warriors wing had failed. Then, using electronic strain gauges affixed to wing and spar surfaces, the engineers recorded the structure's reactions to G-loads applied in flight. The results confirmed the computer's diagnosis.

FAA Designated Engineering Representative Victor Juarez then designed a small, artfully tapered gusset that bridges the critical area, eliminating the stress concentration. The GAMI team hardened the perimeters of rivet and bolt holes in the affected area, increasing their lives several-fold. The FAA approved the modification without testing a wing, solely on the basis of extensive analytical documentation the company supplied.

GAMI intended to turn over the rights to the AMOC to the T-34 Association, but to Braly and Roehl's surprise, the association's board chose not to involve itself in the airframe repair business or to endorse any particular AMOC. So Braly and Roehl formed the T-34 Spar Corporation, which provides the required inspections and modifications at a number of sites for $14,000.

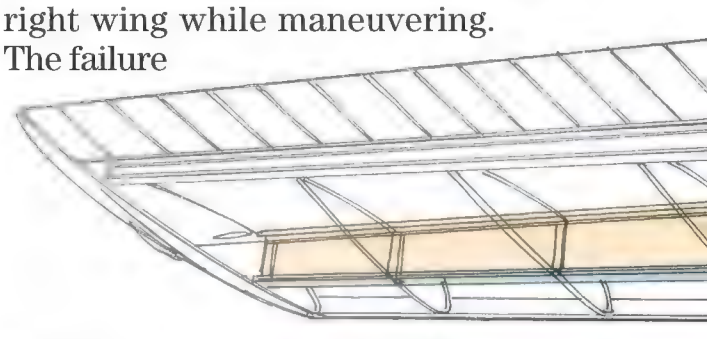
The costliest repair is offered by Nogle & Black Aviation of Tuscola, Illinois. Charlie Nogle and his son Jud are, like Earle Parks, longtime eminences in the T-34 community. The Nogles scrap the existing spars and replace them with one more massive and better made than the original. The new spar also provides a shear web that runs all the way out to the wingtip (the original T-34 web stops a little outboard of the landing gear). The full-length web looks stronger, but its real function is to provide support for supplemental rubber fuel bladders in the leading edges outboard of the standard tanks, whose 50-gallon capacity may not be enough for the bigger-engine airplanes.

New spars—two are required—cost around $12,000 each, and the additional cost of dismantling the airplane and wing and refurbishing the wings as needed (it would be foolish to take the wings apart and not bring them up to near-new standard) runs another $12,000 to $20,000. Nevertheless, says Jud Nogle, the mod sells itself. "Pilots take one look at the new spar next to an old one, and they want to have it."

T-34 owners grumbled over the cost of modifying their airplanes. Many felt that the FAA had overreacted to the cracks. After all, only one airplane had had the problem, and that airplane, they felt, had been systematically abused. The same might be true of all airplanes used in air combat schools, which also provides "upset training" to pilots wanting to learn to recover from unusual attitudes, such as those produced by an encounter with the wake of a larger airplane. Surely it was unfair to lump them together with the T-34 operators who used their airplanes primarily for weekend outings and formation flights, and who rarely, if ever, indulged in acrobatics. It was rumored that in addition to the fatal Sky Warriors accident, a couple of other T-34s had experienced partial wing failures and had flown home to be repaired, and that these too had been air combat school airplanes.

As more and more airplanes underwent eddy-current testing and emerged with clean bills of health, and as more and more of the spars removed and inspected by the Nogle and Parks organizations proved free of cracks, owners and maintainers increasingly complained that the whole business was, as Earle Parks put it, a "fool's errand."

Then, on November 19, 2003, a second wing failed, in nearly a carbon copy of the first: The airplane, operated by Texas Air Aces of Houston, shed its right wing while maneuvering. The failure



The T-34 community came up with four fixes to the fatigue cracking in the spars. The most extensive one—Nogle & Black's—scraps the existing spars and replaces them with a better-made spar.

occurred at the same point as the failure on the first airplane. Both pilots died. The airplane's spars had not been modified, and it seemed probable that the airplane had been operating beyond the 2.5-G, 175 mph limits imposed by the AD.

Now the FAA raised new concerns. It had found cracks in the rear spar of the accident airplane. Owners became frantic, worrying over rumors of a new AD and possible cancellations of the existing AMOC authorizations. In the meantime, stung by suggestions that the local office had looked the other way while Texas Air Aces continued to operate its non-AMOC'ed airplane in violation of the 1999 flight restrictions, the FAA ordered a fine-tooth-comb inspection of all T-34 logbooks, paperwork, and service and maintenance histories.

The resentment many owners felt toward the air combat schools rose sharply. Was there not some way to differentiate between ordinary users and those who routinely applied high stresses to their airplanes?

The difference was not as great as all that, countered Robert Gold, owner of Sky Fighters, a Denver T-34 operator specializing in mock dogfighting and upset training. His company, Gold said, specifically discourages pulling lots of Gs during air combat maneuvering; in fact, it has a "strict and absolute limit of four Gs" and usually pulls no more than 3.5 on a simulated combat mission. Gold summed up the bottom line with an earthily persuasive argument: "It's not that much fun cleaning vomit out of the airplanes." In fact, said Gold, upset training occasionally involves higher G loadings than the "very choreographed" dogfighting does. Other operators of air combat schools flying different aircraft types, such as Siai-Marchetti 260s and Extra 300s, back Gold up. They don't pull lots of Gs because most customers don't like it.

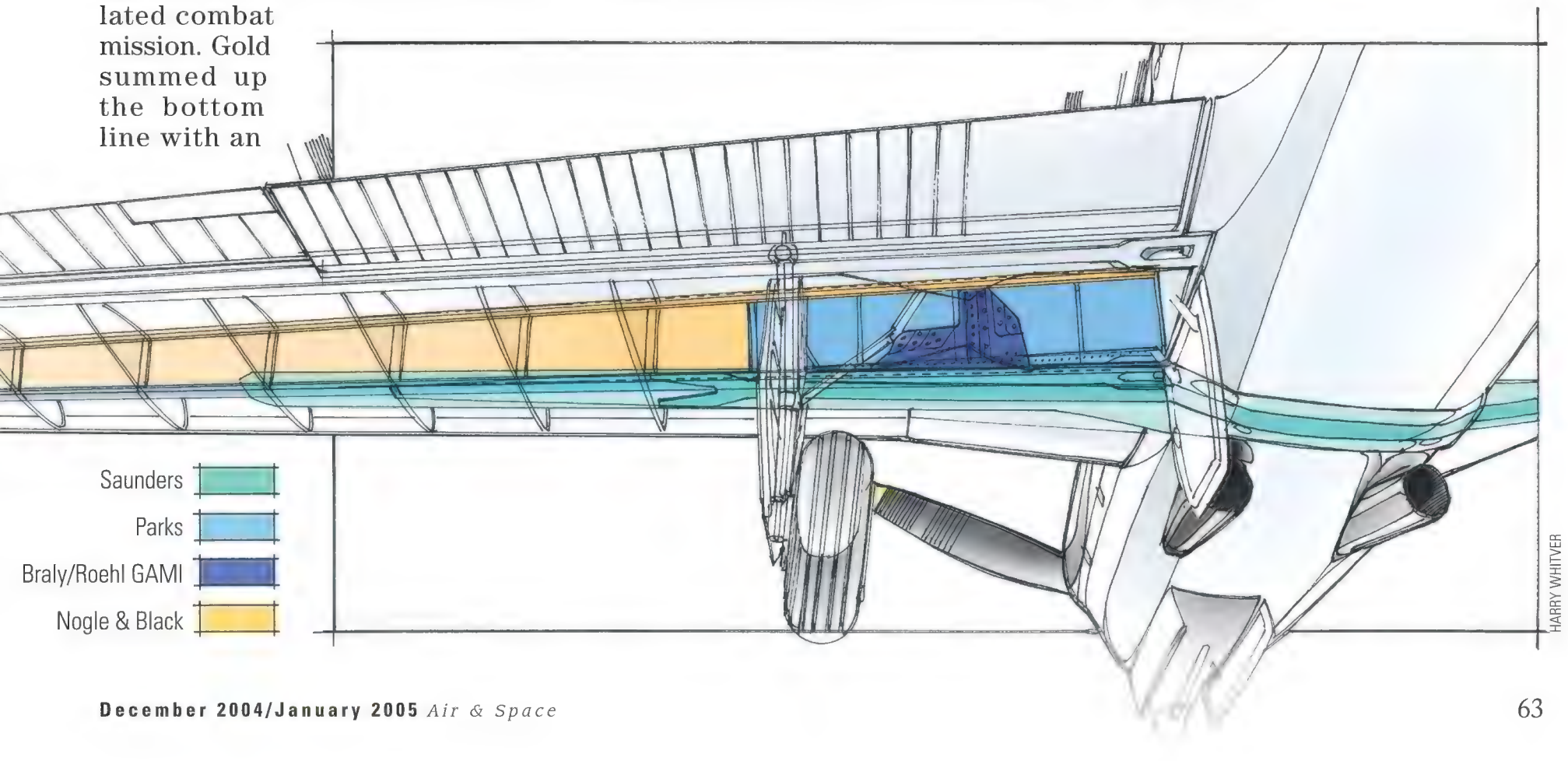
The FAA had already turned a cold shoulder to the proposal that combat school airplanes be treated differently, arguing that because parts of airplanes often get exchanged without detailed record-keeping, it is impossible to know the service history of, say, a given set of wings. Nevertheless, it began to categorize T-34s as Type 1, those used in aggressive air combat or upset training, and Type 2—all others.

Early in March, the FAA published the latest revision of the T-34 AD. Citing new cracks found in the vicinity of the landing gear pivot fitting on the rear spars of several aircraft, it cancelled all the existing AMOCs and grounded, as of March 15, all T-34s that were not in compliance with the original 80-hour-interval Raytheon inspection requirement.

T-34 owners were furious. "Great news, guys!" announced one sarcastic posting on *www.T-34.com*. "Scrap aluminum hit .71 a pound today!" Another presented a sketch of a T-34 mounted atop a house as a weathercock, labeling it the FAA's "final AMOC." A new wave of resentment against combat schools arose, with the same arguments pro and con.

This time, the dust settled quickly. Holders of AMOC authorizations modified them to include inspections of three rivet holes in the rear spar, and the FAA, by now accustomed to working cooperatively with representatives of the T-34 community, reinstated the AMOCs without delay. The FAA also terminated the sweeping program of inspections of T-34 paperwork, not having found enough discrepancies to justify continuing with it. T-34s were soon flying again; Lima Lima's exhibition schedule barely missed a beat. Once a T-34 had emerged from the inspection and modification process with a clean bill of health, the re-inspection period was extended to intervals that represented, depending on the work done, anywhere from several years to a lifetime of flying.

Nevertheless, pilots would be watching G-meters now, and in the back of their minds would be the worry that somewhere—if not in their own airplane, then in someone else's—a fatigue crack might be starting to form. Like an athlete who discovers in his 40s that his body can no longer take the punishment it used to, the T-34 was passing into a new phase: not old age, but perhaps middle age, a time for reflection, restraint, and an awareness of mortality.



HARRY WHITVER

Fork-tailed Devils and Flying

The OV-10 survived low, slow missions because of redundant control systems in its booms.

Why two tail booms are sometimes better than one.

by Mark Gatlin

Twin Shoes

They look odd. Even though aircraft with twin tail booms have appeared in every era of aviation history—from the early designs of the Farman and Voisin brothers to Adam Aircraft's turbofan twin awaiting FAA certification—each one looks like a fix to something broken, an escape route from a corner into which a designer has painted himself.

Why do it? Why shorten and interrupt the fuselage and connect the wings to the tail assembly with two tubes? There are as many reasons as there are twin-boom designs. Booms have been used to shave weight, stiffen structure, give fighter pilots better aim, improve the efficiency of propulsion systems, reduce parasitic drag, and expedite the loading of munitions or cargo—sometimes all on the same airframe. Examining the various rationales for the configuration is a good way to understand just how many trade-offs aeronautical engineers have to make to build an airplane that will not only get off the ground but do something useful after it does. As this collection shows, twin-boom aircraft have been useful at almost everything the more familiar single-tail-boom airplanes do. The ones shown are merely a sample of hundreds of designs. (For more twin tail-boom airplanes and photos of aircraft mentioned but not pictured here, visit *www.airspacemag.com*.)

Twin-boom designs are still making history. Burt Rutan's SpaceShipOne, the first private craft to take an astronaut into space, and its dashing launch platform White Knight both have twin tail booms. And if the movies are any guide, the configuration will be flying long into the future: In Ridley Scott's 1979 science fiction classic *Alien*, the vehicle transporting man's greatest threat is a giant spacecraft with twin booms.

Cessna 337 Skymaster

SON OF A HOMEBUILT

The North American OV-10 Bronco owes its successes during the Vietnam War to the tenacity of two Marine Corps majors, K.P. Rice and Bill "Flameout" Bennett. In 1961 no one was interested in a small, short-takeoff-and-landing aircraft designed to support troops who were fighting guerrillas. But Rice and Bennett knew what was needed and built it in Rice's garage. It was going to "dive bomb like a Stuka or an SBD, maneuver like an SNJ/AT-6, and be as fast and strong as a Corsair," Rice remembers saying to anyone who'd listen. Obsessed with installing a 106-mm automatic recoilless rifle on the centerline, they added twin booms to lift the empennage out of the back blast. The Lockheed P-38, Rice says, had already demonstrated that placing guns on the centerline increases the shooter's accuracy. Why the 106 rifle? "We were going to hit targets," Rice says, "not surround them with bombs." Twin booms also enhanced survivability, because redundant control systems were in the booms, widely separated. The military services came around to the need for a counter-insurgency aircraft, but in designing one, they increased its size, weight, and variety of missions—and dropped the 106. Still, the Bronco in its final form was a potent warplane. Kit Lavell, a pilot with a Navy OV-10 squadron known as the Black Ponies, says proof of the aircraft's effectiveness in supporting SEALs and riverine forces was that "the enemy prepared crude handbills with the shape of the plane depicted on them and prescribed tactics to shoot down the Bronco."

LEFT: GEORGE HALL/CHECK-SIX; ABOVE: NASM (SI NEG. #00020201)

CENTERLINE THRUST

Adam Aircraft expects the Federal Aviation Administration to certify its new push-pull, twin-boom business aircraft, the twin-engine A500, within the next few months. It's a new airplane but an old idea. The concept of centerline thrust took shape most recently in the Cessna 336.

When it debuted in 1964, the 336 crowned years of development toward a simple, low-cost aircraft offering the safety of two engines without the conventional twin's tendency to yaw if one engine fails. Twin tail booms made room for the second engine at the rear of the fuselage, and the two engines provided centerline thrust and a comfortable ride. A year later Cessna brought out the 337 Skymaster, which had more powerful engines and retractable landing gear. It was a controversial airplane. Despite the safety-oriented sales pitch, the Skymaster's accident rate was higher than that of conventional twins. Hangar wags referred to it not as the Skymaster but the Mixmaster. But in 1966 the Air Force liked the 337's high-wing visibility and ability to use short, rough fields, and it bought the twin as a forward air control craft. More than 500 of the 337s were fitted with rocket pods and smoke generators and shipped to Southeast Asia as Air Force O-2s. Author and O-2 pilot Robert Mikesh says the O-2 "felt civilian" and recalls "one ham-handed guy literally pulling the door handle off," but gives it "a 9 on a scale of 10" for mission suitability.

A new take on centerline thrust: Adam Aircraft's twin-engine A500.

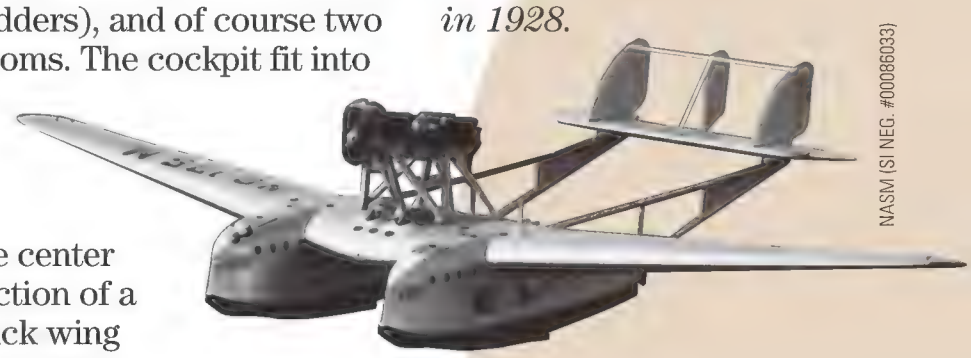
ADAM AIRCRAFT

NASM (SI NEG. #00010700)

TWIN BOOMS WITH SEA LEGS

Making headlines around the world—and earning propaganda dividends for Italy's Fascist government—for a series of transatlantic flights in the 1920s and '30s, the unique Savoia-Marchetti S.55 flying boat had two engines, two hulls, two tail fins (and three rudders), and of course two booms. The cockpit fit into the center section of a thick wing supporting engines with pusher and tractor props mounted in tandem on centerline pylons. Designed as a torpedo bomber and minelayer but seeing no action in World War II, the S.55 is best remembered for a July 1933 stunt when 24 of them flew from Rome to Chicago. Led by Italy's flamboyant young air force general, Italo Balbo, the formation arrived for the World's Fair in a little over 48 hours. (According to National Air and Space Museum archivist Brian Nicklas, the performance so impressed the world that for years any large formation of aircraft was referred to as "a Balbo of airplanes.")

The Bv 138 (above) attacked convoys, resupplied U-boats, and swept for mines mostly in Scandinavian waters. The S.55 (below) must have made Italians feel communal; a formation of 61 crossed the Mediterranean in 1928.



NASM (SI NEG. #00086033)

In the following decade, a twin-boom amphibian, the single-hull, tri-motor Blohm und Voss Bv 138, nicknamed the Flying Shoe, attacked Allied ships in the north Atlantic and distinguished itself by engaging in a dogfight with a Consolidated Catalina flying boat—and winning. Bv 138s menaced Allied convoys, but by late 1942 they were being quickly rendered obsolete by the deployment of Allied aircraft carriers and their fighters. On May 1, 1945, one of the few remaining Shoes alighted under fire on a Berlin lake. Its mission was to pick up and deliver two envelopes, but the pilot ignored the order and instead picked up 10 wounded and delivered them to Copenhagen, Denmark. In those envelopes, it was later found, was Adolph Hitler's last will and testament.

A BUNCH OF GHOULS

When the de Havilland D.H.100 Vampire was designed in 1942, the turbojet was an immature technology. The jet pipe had to be kept short to limit loss of thrust from the anemic Goblin engine. So the engine was installed behind a short, molded-plywood cockpit. Shaving weight, skinny twin booms were employed to lift the tail assembly clear of the exhaust. Empty, the airplane weighed a mere 6,372 pounds.

The Vampire appeared too late to joust with the Me 262, but in 1945 it became the first fighter to exceed 500 mph and the first jet to land on an aircraft carrier.

In 1951, de Havilland debuted the D.H.112 Venom, evolved from the Vampire with a Ghost engine (again the ghoulish theme), which was 40 percent more powerful than the Goblin. By 1960, when this Addams family of twin-boom jets culminated with the all-weather, swept-wing D.H.110 Mk. 2 Sea Vixen, the booms were called on to do more than support the tail assembly. Packed with tanks, they were extended forward of the wings to carry more fuel for the two 10,000-pound-thrust Rolls-Royce engines.

BELOW: CRAIG JUSTO/AERO ASPECTS; RIGHT: JOHN M. DIBBS/THE PLANE PICTURE COMPANY

Its pilots called the Vampire (left) an "aerial kiddy car." Today, the only flying Sea Vixen (above) is privately owned in England.

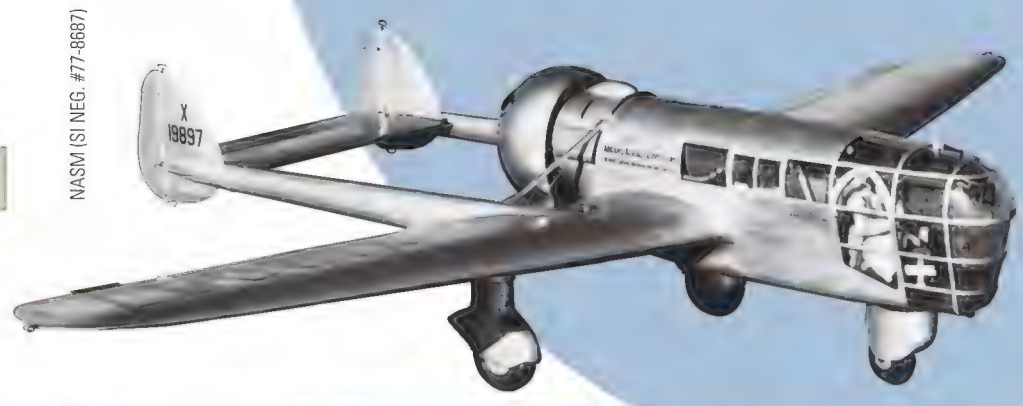
LOCKHEED'S LEGEND

Called "the fork-tailed devil" by the Germans, the Lockheed P-38 Lightning was also called "funny-looking" by the U.S. Army when its representatives saw the design in early 1937. Lockheed designer Kelly Johnson famously wrote in his autobiography that by the time the Lockheed team had stuffed the long Allison inline engines into nacelles with turbo-superchargers and landing gear, "we were almost back to where the tail should be. So, we faired it back another five feet...." Johnson needed two 1,150-horsepower Allison V-1710 engines to achieve the required speed of 360 mph (the operational fighter bested 400) and climb rate of 20,000 feet in six minutes. The design enabled him to cram in all that propulsion with the smallest drag penalty. The centerline cockpit nacelle allowed for good visibility and carried four machine guns and a cannon—a devastating stream of forward fire without the complication and weight penalty of an interrupter gear to keep the guns from shooting a propeller blade.

Although the P-38 is the most famous twin-boom combat aircraft of World War II, it is not the first. That distinction belongs to the Fokker G.1, which first flew in 1937, two years before the XP-38.

A distinguishing feature of the other U.S. twin-boom fighter to enter service during the war, Northrop's P-61 Black Widow, was the big radar in its nose, which enabled it to fly missions at night. It carried up to three crewmen in the central fuselage, four belly-mounted 20-mm cannon firing forward and, in some models, a powered, remote-controlled turret equipped with four .50-caliber machine guns. Gerald H. Balzer, a former Northrop engineer, says the design team worked from a sketch made in 1940 by the Air Technical Service Command at Wright Field in Ohio. His thoughts on the twin-boom arrangement: "The configuration of an airplane depends on what you want to cram into it."

NASM (SI NEG. #00047407)



NASM (SI NEG. #77-8687)

OPPOSITE: © PHILIP MAKANNA/GHOSTS

THE FIRST STRATEGIC BOMBER

Giulio Douhet and Gianni Caproni could be considered the twin pillars of Italian air power in World War I. Because of their collaboration, says historian John H. Morrow Jr. of the University of Georgia, "Italy put up a very strong aerial effort in relationship to its economic resources." Morrow adds: "Douhet believed that you could knock another country out of the war by bombing strategic targets—hydroelectric plants, railway stations and junctions, ammunition stockpiles, and factories. And Caproni was willing to design large aircraft to do just that."

With a wingspan of 73 feet, Caproni's Ca.3 biplane bomber was one of the largest aircraft fielded in World War I, almost 20 feet wider in span than the war's other twin-boom biplane bomber, France's Caudron G.4. (It was a big-airplane war: Handley Page built a four-engine giant with a 120-foot wingspan.)

Like so many of its contemporaries, the Caproni bomber used a combination of pusher and tractor propellers; Caproni placed the pusher at the rear of a short, bathtub-like fuselage, the only ungraceful feature of a beautifully proportioned airplane. Its most famous missions were low-level night raids, flown in 1917 across the Adriatic Sea, to surprise the Austro-Hungarian fleet while it was at anchor in Pola (today Pula), Croatia.

The year before, a second gunner's position was added above the rear engine. "It must have been a ferociously difficult position," says Morrow, the author of *The Great War in the Air* (Smithsonian Institution Press, 1993). "It was located up and in the slipstream and the weather. Many of those crews won Italy's highest honor for bravery in combat. I marvel at what men did in World War I."

NASM (SI NEG. #00018387)

Strategic bombing, Italian style: the Caproni Ca.3.

A MACHINE FOR SEEING

What must the view have been like from the Abrams Explorer? The two-place crew nacelle, pushed so far forward that not even the wings encroached on the scenery, was glazed top and sides with plexiglass, like the nose of a World War II bomber. Flying by November 1937, the Explorer was one of the first U.S. aircraft with a twin-boom configuration, used so that the radial pusher engine could be mounted aft, where it wouldn't block the view. It is one of only a few aircraft of any configuration designed solely for surveying and mapping. Early on, the Army was interested in Talbert Abrams' camera platform, but decided instead to convert fighters for combat photo reconnaissance. Civilian markets didn't materialize.

Undaunted, the former Marine pilot went on to start the ABC Airline ("Always Be Careful") and was famous throughout hometown Lansing, Michigan, for his airplane-shaped house. Today, his Explorer is awaiting further restoration at the National Air and Space Museum.

At virtually the same moment Abrams was creating the Explorer, across the Atlantic another twin-boom aircraft was being designed and built for maximum visibility, but the client had no interest in surveying. Conceived in February 1937 and flying by July 1938, the Luftwaffe's Focke-Wulf 189 Uhu (Owl), known as Das Fliegende Auge (the Flying Eye), had small, air-cooled engines and retractable gear in the booms and a generously glazed central nacelle on top of the wing. Though armed with six machine guns, two cannon, and, at times, spray canisters of mustard gas, most 189s flew short-range reconnaissance missions on the Eastern Front. One was a personal transport for Albert Kesselring, a supreme commander of German air and ground forces.

Only one Abrams Explorer (above) was built. Opposite: Lefty Gardner's P-38 (top) was one of several that electrified air racing fans before a 2001 crash. The Fokker G.1 (bottom) is found only in museums.

SAMUEL VICK SMITH

Burt Rutan's world-circling Voyager.

GOING GLOBAL

To make the first nonstop, unrefueled flight around the world, Burt Rutan designed a flying fuel tank. "The Voyager booms hold a large percentage of the fuel," Rutan says, "and [the fuel] had to be mounted along the span to keep the wing spar from being too heavy." Two tanks in each boom, four in each aft wing, one in each canard, and three in the fuselage held 7,000 pounds of fuel, or 72 percent of the craft's gross takeoff weight.

The long, thin wing was not stiff enough to support the booms. Rutan's solution was to stiffen the structure by connecting the forward tips of the booms to a canard wing to hold them in position and keep them from twisting the main wing. To conserve fuel, the aircraft was to be powered most of the trip by one engine (the pusher), so Rutan mounted both engines on the centerline. After its nine-day flight in December 1986, Voyager landed with just 106 pounds of fuel, or about 16 gallons—enough for a little over three hours' flying.

Twin booms are becoming almost as much a hallmark of Rutan's designs as the ever-present canards. He also uses the configuration on the Global Flyer, in which record holder Steve Fossett intends to attempt another solo around-the-world flight before April 2005.

U-2SK

Vladimir Mikhailovich Myasishchev initially created the M-17 Stratosphera (that's "Mystic," to NATO) to shoot down U.S. reconnaissance balloons. By the time of its 1982 first flight—after its designer's death—it had lost its gun turret and become a spyplane. The design was probably influenced by two earlier projects: the twin-boom Sukhoi Su-12, a 1947 piston-engine recce aircraft that went only as far as prototype, and the Yakovlev Yak-25RV, a high-altitude reconnaissance jet with sailplane-like wings similar to those of the M-17. The Mystic could loiter for four hours at 65,000 feet, but it never achieved the altitude performance of the Lockheed U-2, its U.S. counterpart. Its short fuselage is the single design advantage the M-17 had over the U-2. Says aviation historian Jay Miller, "Jet engines—regardless of whether they are turbojet or turbofan—lose efficiency depending on the length of the exhaust pipe. The U-2's fuselage and associated lengthy engine exhaust tube have historically been one of its few Achilles' heels." A twin-engine descendant, the M-55 Geophysika, flies atmospheric research missions, just as NASA's ER-2 research craft—civilian versions of the U-2—do in this country.

MYASISHCHEV DESIGN BUREAU

The high-altitude M-55 is being considered as a launch platform for a space tourism vehicle.

RIGHT: COURTESY FAIRCHILD VIA NASM (SI NEG. #91-1809)

GUNBUS

In aviation's baby days, twin tail booms were an answer to the question "Where do we put the propeller?" Before Anthony Fokker's 1915 invention of a mechanism to synchronize the firing of a machine gun with the spinning of propeller blades (the gear first appeared on the Fokker E.1 Eindecker fighter), placing the engine and propeller behind the fuselage cleared the way for a gun in the nose. The U.S. Army banned pusher engines in 1914 after several pilots died in crashes, but many European World War I aircraft used them. The first British airplane designed as a fighter, the Vickers Fighting Biplane 5, also known as the "Gunbus," had a pusher, as did the Airco D.H.2. Both fighters used a fixed forward gun—and were frequently shot down from the rear.

Geoffrey de Havilland's first work as chief designer of the Aircraft Manufacturing Company, Ltd. in 1914: the D.H.1.

NASM (SI NEG. #2001-3807)

In 1952, the prototype YC-119H got extended wing and tail surfaces.

US NAVY

FENCED IN

Former Secretary of the Navy John Lehman became a believer in unmanned aerial vehicles in 1983. After the bombing of a U.S. Marine Corps barracks in Beirut, Lehman viewed a video shot by an Israeli UAV. It showed the Marine commandant inspecting damage. The aircraft had been so inconspicuous that the general had no idea he was on camera, yet Lehman easily recognized the man. The U.S. Navy's RQ-2A Pioneer UAV was born.

Like the Israeli Scout, from which it evolved, the 450-pound Pioneer has 40 pounds of sensors and cameras up front, balanced by a two-cylinder, 26-hp gasoline engine and pusher propeller behind. Steve Reid, program manager for Pioneer UAV Inc., says the booms, besides supporting the tailplane, have served as a fence around the propeller, preventing injuries in the tight shipboard and battlefield environments where the Pioneer operates.

An RQ-2, rocket-launched in '86 from the USS Iowa.

OPEN WIDE

The U.S. Army Air Forces needed a dedicated military cargo plane so desperately in 1942 that General H.H. "Hap" Arnold ordered development of the Fairchild C-82 Packet after seeing only a rough sketch. Twin tail booms, a high wing, and a low-hung fuselage allowed most wheeled vehicles to drive right into the cargo bay. It had enough room for 44 paratroopers or 2,870 cubic feet of cargo—the size of a standard railroad boxcar, hence its nickname, the Flying Boxcar. Packets, however, played no role in the war. By 1948 the C-82 needed a host of modifications (though not the hatchet job performed by Jimmy Stewart and castmates in the 1965 movie *The Flight of the Phoenix*). The result, the C-119, now officially the Flying Boxcar, carried more cargo and paratroopers farther and faster. It served in the Korean War, playing a critical role in the Chosin Reservoir breakout in December 1950 by dropping eight bridge sections that created an escape route across a deep gorge (see "Breakout from Chosin," June/July 2000). In Vietnam, AC-119G Shadow and AC-119K Stinger gunships supported ground combat with flares, infrared sensors, and four Gatling miniguns. The Stinger also had two 20-mm Vulcan cannon. Hawkins and Powers Aviation of Turnbull, Wyoming, still flies a C-82 and two C-119Gs (one was just used in a remake of *The Flight of the Phoenix*).

A final version, the XC-120 Packplane prototype, featured a detachable container pod, which mated to the fuselage by means of complicated gear that tucked into the fuselage and booms in flight. World War II Army Airborne legend General James M. Gavin called it "the most significant development ever produced by the American aircraft industry." None were ordered.

SIGHTINGS

In straining to hear ever-fainter radio emissions from distant galaxies, astronomers have built some of the most graceful machines on the planet. The 20-acre collecting dish of the Arecibo Radio Telescope lets enough rain and sunshine through to allow ferns and orchids to grow beneath it (below). Sitting in a natural hollow in the mountains of Puerto Rico, Arecibo remains the world's largest radio telescope more than 40 years after it was built.

New Mexico's Very Large Array (right) took a different approach, combining the signals from 27 dishes to simulate the resolving power of an antenna 22 miles in diameter. The Green Bank Telescope in West Virginia (opposite) went for sheer bulk. The 100-meter telescope is the largest fully steerable dish in use today. Virginia-based photographer Tim Wright notes: "The telescope seems like a marble sculpture until the silence is pierced by a steady, industrial buzzer warning of impending movement. The motor hum builds to a crescendo and climaxes with a clang as metal strains metal. Then the massive structure spins and the dish bows with a speed that belies its enormous girth. After a while, it seems almost alive, moving with free will as it searches the sky."

ROGER RESSMEYER/CORBIS (2); OPPOSITE: TIM WRIGHT

Rich and Dangerous

Howard Hughes, Aviator

by George Marrett. Naval Institute Press, 2004. 256 pp., $27.95.

COURTESY STEVEN SHOOP

Howard Hughes pilots the second of his XF-11 prototypes. The U.S. Air Force passed the reconnaissance airplane over in the late 1940s in favor of developing jet aircraft.

Howard Hughes was bitten by the flying bug while golfing, when a pilot flying over the golf course tipped his wings at the millionaire tool company owner. Hughes copied the biplane's registration number from its wing, tracked the pilot down, and offered to pay him $100 a day for flight instruction—in 1926!

Even with daily, top-dollar lessons, Hughes needed more than a year to earn his license, by which time he hoped to eclipse Charles Lindbergh as the country's best-known aviator. He even persuaded the U.S. Department of Commerce to grant him a low-numbered pilot's certificate, bringing him closer to Lindbergh in that trivial respect.

Soon after soloing, he bought a Waco 10 biplane, had the Douglas Aircraft company customize it for twice the purchase price…then cheated Donald Douglas on the bill. Hughes had wanted Douglas to make the Waco safer, a request that belied—or perhaps reflected—his lack of discipline as a pilot; he wrecked airplanes at a frightening rate, several times injuring himself and once killing two crew members. To save money on aeronautical charts, he flew with the road maps handed out for free by oil companies. He ignored air traffic controllers, filed misleading flight plans, identified himself by the name of his copilot, flew under visual rules in bad weather, and more than once cut off the pilot ahead of him in the pattern. Even as a passenger, George Marrett relates, Hughes could turn a routine flight into a debacle.

He owned a fabulous variety of airplanes, including the prototype Douglas airliner. When it had served his purpose, he parked the DC-1 and never looked at it again. He did the same with his built-to-order Hughes Racer, a twin-engine Sikorsky amphibian, a Boeing Stratoliner, his eight-engine "Spruce Goose" flying boat, and scores of other aircraft, some guarded for years by relays of college students; Hughes would forget about both the airplanes and the students.

He didn't even have to own a plane to lose it. In 1955, while testing a French Caravelle airliner, he ordered the salesman off the plane, took off without filing a flight plan, and disappeared. The twin-jet was found days later in Palm Springs, where he had abandoned it.

Of course Howard Hughes was more than an aviator: He made movies, ran an airline, designed a half-cup bra, founded aerospace companies, accumulated billions of dollars, and became the country's most famous germophobe. But those are incidentals for a fellow pilot like Marrett, who flew a prop-driven

BRIEFLY NOTED

Little Joe: Mercury's First Steps

directed by James Duffy. Rocket.Aero, 2004. DVD, 130 min., $19.95. Available from www.rocket.aero.

This short film documents the short rocket atop which NASA tested the escape tower designed to thrust Mercury capsules away from exploding boosters. Slow-motion footage of launches, dozens of photographs, and a conversation between director James Duffy and serious modelers make the DVD of interest primarily to modeling enthusiasts.

Skyraider in Vietnam, wrote about it in *Cheating Death*, and afterward became a test pilot for Hughes Aircraft Company. By concentrating on the aviation aspects of his former boss' life, Marrett has given us a short, readable, and continually fascinating biography. In his telling, Hughes turns out to be a heck of a lot more interesting than Lindbergh, even if Hughes never came close to rivaling him as an aviator.
—Daniel Ford flies a Piper Cub and has never forgotten where he left it.

Air Fare: Stories, Poems & Essays on Flight

ed. by Nickole Brown and Judith Taylor. Sarabande Books, 2004. 237 pp., $16.95.

Had my eyes not abandoned my cause in the fifth grade, I might be able to relate to the collections of air combat memoirs that are so frequently published. I would have been a fighter pilot, not an editor, and able to vouch for the emotions experienced when, say, one is locked in a death spiral with a Sukhoi or a Focke-Wulf. Perhaps that's why I so enjoyed *Air Fare*, which seems to chronicle the misanthropy of everyday air travel—a subject to which I *can* relate.

Take, for instance, the inclusion of an excerpt from Colson Whitehead's novel *John Henry Days* in which a businessman scours an airport terminal for receipts so that he can be reimbursed for meals others have purchased, then wages an unspoken turf war with another passenger over the unoccupied airliner seat between them. The early placement of such a passage helps to set a wonderfully odious tone for the anthology.

The editors, Nickole Brown and Judith Taylor, have also made sure to address the holy trifecta of air traveler fears: hijackings, crashes, and crying babies—the last in Natalie Serber's short story "This Is So Not Me," in which the physiology of breastfeeding takes a startling central role.

More than half the selections are written by women—a staggering percentage for anything aeronautic—and thus much of *Air Fare* has a noticeably feminine edge. Brown and Taylor have included a poem inspired by Amelia Earhart, one entitled "Lt. Col. Valentina Vladimirovna Tereshkova," after the cosmonaut, and another with instructions that it should be read in the voice of Jacqueline Cochran, the first woman to break the sound barrier.

If such premises make you cringe, skip to Ellen Bass' "Gate C22," about a gawk-worthy display of public affection, or "Romantic Fatalism," in which Alain de Botton calculates the odds of falling in love on a Paris-to-London flight.

While *Air Fare* also comprises entries such as the poem "Gus Grissom Way," about a space program-theme housing development, and the star-crossed AWACS crew love story "Bluegrass Saved My Life," the collection is better when it avoids space and combat and musings on history, better when it sticks to prose, better when it doesn't stretch the bounds of its theme—as it does with an excerpt from Ian McKewan's novel *Enduring Love* about a hot-air balloon tragedy. It's at its best when embracing the truth that everyone in commercial air transportation would rather be somewhere else.
—Sam Goldberg is an Air & Space/Smithsonian *associate editor.*

TERMINAL HISTORIES

Naked Airport: A Cultural History of the World's Most Revolutionary Structure

by Alastair Gordon. Metropolitan Books, 2004, 320 pp., $27.50.

Airports: A Century of Architecture

by Hugh Pearman. Harry N. Abrams, 2004, 240 pp., $75.

No other branch of architecture is as complex and dynamic as the airport—at once comforting and uplifting, practical and symbolic, local and international. Critic Alastair Gordon makes that case in *Naked Airport*, a richly illustrated and highly readable account of airport design as a social phenomenon driven by the unpredictable combustion of technology and politics. The opening chapters could stand alone as a primer about early civilian aviation worldwide; particularly fascinating are comparisons between the sophisticated and rapidly developing European air network following World War I and the more haphazard system of American air fields.

Naked Airport is strongest when tracing the complicated lineage of airport terminals from their beginnings as sheds and tents, through the many regional building styles around the world, to recent practical demands like anti-terrorism security requirements, urgency for floor space to produce huge retail revenues, and "feng shui charm for redirecting the movement of international capital." Airport design follows the requirements of airplanes, people, and ground transportation, and no matter how modern the designs, the buildings become obsolete overnight.

Airports: A Century of Architecture succeeds as a comprehensive visual record of airports around the world from 1904 to 2004, as a coherent history of a specialized architectural genre, as a credible explanation of modern airports as city-states, and, finally, as pure architectural inspiration.

Author Hugh Pearman, who is architecture correspondent for the *Sunday Times* in London, observes that aircraft themselves are relatively permanent in design—the productive lives of some extend to decades—while airports are constantly changing and nearly always inadequate by some measure or other. His outlook is optimistic, though, not only because of the soaring architectural grace that is now easier to attain technically, but also because evolution is constant. Airports closes with six intriguing "futures" of airport design.
—Nan Chase lives in North Carolina and writes about architecture and interior design.

Hispano Suiza in Aeronautics: Men, Companies, Engines and Aircraft

by Manuel Lage. SAE International, 2004. 495 pp., $59.95.

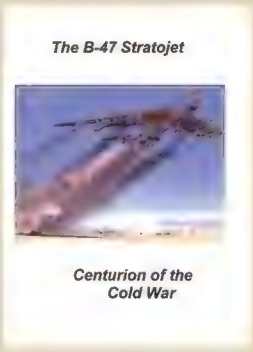
Manuel Lage holds three engineering degrees and apparently knows more about the history of Hispano Suiza than any living person. Readers of *Hispano Suiza in Aeronautics* might conclude that he knows too much. Equipped with enough detail to satisfy the nerdiest engineer, Lage plows through more than 50 years (1913 to 1967) of this company's aviation history.

Most people associate the Spanish company's name with its cars, which

BRIEFLY NOTED

The B-47 Stratojet: Centurion of the Cold War

by Sigmund Alexander. CCCP Publishing, 2004. 224 pp., $30. Available from the author: (210) 653-5361.



This self-published history by a former B-47 pilot is exhaustive and more detailed than previous volumes on the first U.S. swept-wing jet bomber.

began appearing in 1904 from the skilled hands of engineer Marc Birkigt. The cars were fast, fashionable, and sought-after. One, the Alfonso XIII, was named for the King of Spain, an investor.

Hispano Suiza's aeronautical successes began during World War I with the Tipo 34 V8 engine, built at its Paris factory. The 220-horsepower T-34 Hisso, powering the 200-mph French SPAD XIII, won such fame that the Germans copied it. The type numbers of HS piston engines ended at 101 in 1949, and a handful of jets and diesels followed. Most of these ended in the prototype stage, but Lage covers them all.

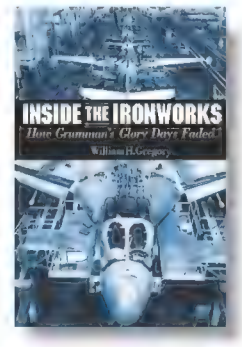
He also addresses every HS aircraft built in Spain, using a confusing parallel construction. This makes it difficult to make your way through the interweaving of licensed builders, original designers, and corporate name changes. That the book was translated from Spanish does not help matters.

Still, nuggets of historical gold emerge from the slag heap of Hispano Suiza minutiae. For example, the book documents engineer Birkigt's extraordinary talent. He designed the HS-404, better known as the 20-mm guns fitted to flocks of Allied aircraft in World War II. Patient readers will learn that Hispano Suiza survived honorably under Spanish dictator Francisco Franco and the Nazi occupation of France. To do so, Hispano Suiza built cars, airplanes, engines, furniture, guns, machine tools, and even the Anglo-French Concorde's landing gear.

A tough read, but Hispano Suiza enthusiasts will find it well worth it.
—William Jeanes lives in Pass Christian, Mississippi, and is a former editor-in-chief of Car and Driver.

Inside the Iron Works

by George M. Skurla and William H. Gregory. Naval Institute Press, 2004. 256 pp., $32.95.

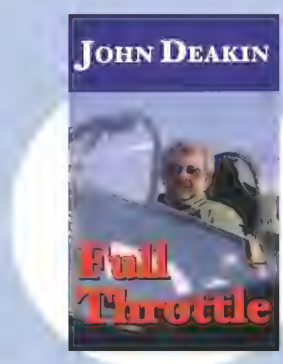


The late Steven Ambrose admonished writers of history to "Ignore chronology at your peril." It's a pity that William H. Gregory, who did the heavy lifting on *Inside the Iron Works*, missed that advice. Co-author George Skurla, a disillusioned former Grumman executive, can be excused because he died in 2001. Gregory's preface warns that the book is a personal history and not history in the textbook sense, but there's no warning of its meandering and confusing nature. Those seeking Grumman corporate esoterica, however, might find Skurla's executive suite revelations illuminating.

Skurla came to Grumman as an apprentice engineer in 1944 and remained for 42 years. Following his success as Grumman representative at the Kennedy Space Center during the Apollo program, his star rose. He became president of Grumman Aerospace in 1974, and chairman and CEO in 1976. Nine years later he became president of the parent Grumman Corporation. He retired in 1986.

The company had been founded on Long Island in 1930 by Roy Grumman and five associates. It quickly became a distinguished contractor for the Navy and remained so until its sad end, when

SHORT HOPS

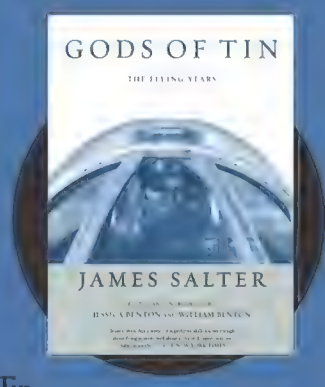


Full Throttle

by John Deakin. Fly-Bye-Knight Press, Inc., 2004. 292 pp., $34.95.

Anyone who has seen the 1990 Mel Gibson-Robert Downey Jr. movie *Air America* (not one of either's best) knows the basic story of the CIA's very own airline, which shipped guns, ammo, grain, pigs, and who knows what else around Southeast Asia during the Vietnam War. John Deakin, a 37,000-hour pilot, flew for Air America—and for a few other airlines as well. Air America provided a chest-hair-growing experience: Company men regularly piloted overloaded airplanes on and off too-short dirt strips in all weather except snow (it was Southeast Asia).

More than merely recounting his experiences above Laos, Deakin describes his career, from flying surplus World War II bombers as a teen in the Bahamas to his last trans-Pacific 747 trip for Japan Air Lines. He goes a little heavy on the exclamation marks ("Gosh, airshows are fun!" he writes), but pilots will still enjoy this book. Where else, along with all those war stories, can you get a step-by-step descripton of firing up a Grumman Bearcat, a Hawker Hurricane, or a Curtiss C-46?
—Phil Scott



Gods of Tin

by James Salter. Shoemaker & Hoard, 2004. 150 pp., $24.

This is Salter's scrapbook, and like most scrapbooks, it is uneven. The author flew F-86 Sabrejets in the Korean War and chronicled fighter operations there in his novel *The Hunters*, his autobiography *Burning the Days*, and other works. He is an exceptionally gifted observer and writer; here is how he explains the crucial difference between the F-86s and their opponents: "They had cannon—the maw of a MiG seemed swollen and menacing. We had machine guns, which were almost feminine in comparison."

Salter's up-front description of learning to fly is probably the most graceful ever written of the experience. But it is followed by a series of unrelated journal entries, sections of the autobiography, and scenes from *The Hunters* (Pell, the hotdog played by Robert Wagner in the film version, is back), all jumping from past tense to present and back again. *Gods of Tin*, a good insider's look at jet combat, is therefore best read with time taken between chapters.
—William E. Burrows

Northrop absorbed the company in 1994.

Grumman built the Navy's F6F Hellcat fighter, which accounted for 4,947 of the Navy's 6,477 kills in World War II. It also built the TBF Avenger torpedo bomber. Grumman designs became known for strength and survivability, hence the company's nickname "the Iron Works."

The F-14 Tomcat and the A-6 Intruder were Grumman designs, as were the Apollo Lunar Modules. Its best known civilian aircraft were the late-1930s Goose amphibian, the Ag-Cat cropduster, and the Gulfstream business aircraft.

Skurla argues compellingly that too-cozy relationships between government and military contractors are more myth than reality. He cites harsh contracts that put companies in the insane but real situation of losing money on each airplane and hoping, as the old joke goes, to make it up in volume. He claims that, beginning with Robert McNamara in the Kennedy administration, relations between military contractors and the Secretary of Defense have deteriorated, though he notes that Grumman's longstanding closeness with the Navy "was never really shattered, but it did fade." Grumman itself faded with the end of the cold war and concomitant military cutbacks, helped by ill-advised stabs at diversification and the unconscionable spinoff of the Gulfstream jet operation, "because we didn't know how to sell it." An air of regret hovers over these and other stories of lost opportunity.

Inside the Iron Works will interest those with connections to Grumman; for outsiders, its best use is as a catalog of missteps to avoid should you become head of an aircraft company.

—William Jeanes

Ultimate Mars Rover

Dorling Kindersley, 2004. $29.99. Available from www.dk.com.

Today's toys are wasted on kids. Dorling Kindersley's Ultimate Mars Rover is a case-in-point. It took me a couple of hours to put together the kit, during which I tapped into my inner geek as well as my inner child. Remember "Score along line A, insert tab B into slot C?" This is how you assemble the plastic parts, stickers, and a pre-built motorized chassis into a model of a rover like *Spirit* or *Opportunity*.

Unfortunately, once I'd completed construction, I encountered the three words one doesn't want to hear on Christmas morning: "Batteries not included."

When powered up, the toy picks up magnetic "soil samples" in a tabletop game involving Mars trivia. To be honest, the game is a lot less fun than the construction of the Rover, and the model is a bit flimsy—it probably wouldn't last to New Year's Eve.

Despite these caveats, would it entertain an eight-year-old? Probably. Did it entertain a 35-year-old? Definitely.

—Matthew Stibbe

Tex Hill: Flying Tiger

by David Lee "Tex" Hill with Reagan Schaupp. Honoribus, 2004. 318 pp., $31.10.

David "Tex" Hill was one of the Flying Tigers, the band of fighter pilots who flew for U.S. General Claire Chennault in Burma and China for seven months in 1941 and 1942. If you believe this book, a handful of P-40E Kittyhawks turned the tide of war by halting the Japanese army during a 1942 air-ground action at Salween Gorge in China's Yunnan province.

Hill led a colorful life as an air ace, naval aviator, Air Force squadron and wing commander, and adventurer, but this self-published hagiography is riddled with errors, and an amateurish chapter about "who lost China" attempts to rekindle McCarthy-era anti-communism. Even the byline is misleading. Hill should have written the book, but his grandson, U.S. Air Force Major Reagan Schaupp, did, in the third person. Readers willing to forgive the errors—as in many books published in the West, Japanese aircraft are identified incorrectly—should enjoy this account of the challenges Hill faced.

—Robert F. Dorr

CREDITS

The Long Road Home. Arnold Benson has contributed many accounts of his flying adventures to *Air & Space/ Smithsonian.* In "Thirty Seconds Over Philmont" (Above & Beyond, Aug./Sept. 1999), he wrote about an impromptu flight to deliver clams for a clambake.

The Short, Unhappy Life of the Barling Bomber. Kevin L. Cook is a freelance writer in Oklahoma.

Send in the Global Hawk. A skeptic at first, pilot and writer John Croft ultimately took a liking to the Global Hawk. "Forget that it's an airplane," one observer suggested while Croft watched the unmanned aerial vehicle on the ramp at Edwards Air Force Base. "Think of it as a pet."

The Nightmare of Voskhod 2. Alexei Leonov was selected to be a cosmonaut in 1959 and later served as head of training at the Gagarin Cosmonaut Center in Moscow. *Two Sides of the Moon: Our Story of the Cold War Space Race*, which Leonov wrote with former Apollo astronaut David Scott, was published in 2004 by Thomas Dunne Books.

Vital Signs. Pilot Mark Huber first wrote about Douglas aircraft for *Air & Space* in "High Mileage" (Apr./May 2000), which profiled companies still flying DC-3s .

How Things Work: Hush Kits. Roger A. Mola is a regular contributor to *Air & Space*. He also writes about technology and industry regulation for aviation trade publications.

The Things That Fell to Earth. James E. Oberg worked for 22 years at NASA's mission control center in Houston, Texas. He is a widely published author on past, present, and future space missions around the world and off it. His Web site is *www.jamesoberg.com.*

Save the Mentor! Peter Garrison writes and markets computer software used in designing airplanes, boats, and other streamlined vehicles. His last article for *Air & Space* reported on the meticulously restored warbirds of the Flying Heritage Collection in Arlington, Washington ("Crown Jewels," Oct./Nov. 2004).

Fork-tailed Devils and Flying Shoes. Mark Gatlin, formerly the aviation and spaceflight editor for Smithsonian Institution Press, is the director of the Naval Institute Press.

CALENDAR

December 4
"Search and Rescue!" Family Fun Workshop. Learn about the duties of those who work for the U.S. Coast Guard, then design and build your own air rescue base and try your hand at a rescue mission. Museum of Flight, Seattle, WA, (206) 764-5720.

December 5
Wings of Valor: Medal of Honor Aviators Seminar. Listen to five aviators tell how they earned medals of honor for valor in military action. San Diego Aerospace Museum, Balboa Park, San Diego, CA, (619) 234-8291, *www.aerospacemuseum.org.*

December 11 & 12
Holiday Hangar Hop. Take a tour of airplane-filled hangars. Fantasy of Flight, Polk City, FL, (863) 984-3500, *www.fantasyofflight.com.*

January 8
Cold War Aerial Reconnaissance Seminar. Planes of Fame Museum, World War II Cal-Aero Field, Chino, CA, (909) 597-3722, *www.planesoffame.org.*

Organizations wishing to have events published in Calendar should fax press releases two months in advance to (202) 275-1886 or mail them to Calendar, Air & Space/Smithsonian, *MRC 951, P.O. Box 37012, Washington, DC 20013-7012.*

Statement of ownership, management and circulation (required by 39 U.S.C. 3685) of Air&Space/Smithsonian published bimonthly by Smithsonian Business Ventures, MRC 951, P.O. Box 37012, Washington, D.C., 20013 for October 1, 2004. General business offices of the publisher are located at 750 Ninth Street, N.W., Suite 7100, Washington, D.C. 20001. Name and address of publisher is Amy P. Wilkins, MRC 951, P.O. Box 37012, Washington, D.C., 20013 . Name and address of editor is George Larson, MRC 951, P.O. Box 37012, Washington, D.C., 20013. Owner is Smithsonian Institution, 1000 Jefferson Drive, Washington, D.C. 20560. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities: None. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months (Section 411.3, DMM). The average number of copies of each issue during the preceding 12 months are: a) Total number of copies printed: **280,981**; b) Paid and/or Requested Circulation: (1) Sales through dealers and carriers, street vendors, and counter sales (not mailed) stated on Form 3541: **403**; (2)Paid or Requested Mail Subscriptions (include Advertisers' proof copies/Exchange copies)stated on Form 3541: 228,745; c) Total paid and/or requested circulation: **229,148**; d) Free Distribution by Mail (Samples, Complimentary, and Other Free): **2,117**; e) Free Distribution Outside the Mail (Carriers or Other Means): **9,693**; f) Total Free Distribution: **11,810**; g) Total Distribution: **240,958**; h) Copies not Distributed: (1) Office use, Leftovers, Spoiled stated on form 3541: **3,393**; (2) Return from News Agents: **36,630** ; i) Total: **280,981**; j) Percent Paid and/or Requested Circulation: **95%**. The actual number of copies of single issue published nearest to filing date are: a) Total number of copies printed: **268,995**; b) Paid and/or Requested Circulation: (1) Sales through Dealers and Carriers, Street Vendors, and Counter Sales (Not Mailed) stated on Form 3541: **387**; (2) Paid or Requested Mail subscriptions (include Advertisers' proof copies/Exchange copies)stated on Form 3541: **224,225**; c) Total Paid and/or Requested Circulation: **224,612**; d) Free Distribution by Mail (samples, Complimentary, and Other Free): **2,095**; e) Free Distribution Outside the Mail(carriers or other means): **5,484**; f) Total Free Distribution: **7,579**; g) Total Distribution: **232,191**; h) Copies not distributed: (1) Office use, Leftovers, Spoiled stated on form 3541: **2,725**; (2) Return from News Agents: **34,079**; i)Total : **268,995**; j) Percent Paid and/or Requested Circulation: **97%**. I certify that all information furnished is true and complete.

(Signed) David R. Kefford
General Manager

FORECAST

In the Wings...

The People and Planes of Anoka County
We continue our series of visits to the country's most captivating airports with a stop at Anoka County-Blaine in Minnesota, where we found a bumper crop of airplanes—including a 1911 aerohydroplane—and the homebuilders' spirit intact.

CAROLINE SHEEN

Warbird watchers at Anoka with two T-6s and a Nanching Yak (at right).

Whatever Happened to Mathias Rust?
In 1987, when he was 19 years old, Mathias Rust flew a Cessna 172B through Soviet air defenses and landed in Moscow's Red Square. Our author found him today and asked, "What were you thinking?"

Splash!
Behind the scenes with the Navy frogmen who were the welcoming committee for the Gemini, Mercury, and Apollo spacemen.

New U.S. Spyplane: The Lockheed U-2
Definitely not the same airplane that Gary Powers had a bad day in, today's U-2 is 40 percent bigger, powered by a new engine, and wired up the wazoo. (And its wings—103 feet in span—fold.)

Whistling in the Dark
The universe is flying apart at an ever-faster rate because (a) a force known as dark energy is tearing it asunder, (b) it has sprung a gravity leak, or (c) virtual particles have overdrawn their energy accounts. Would you believe that astrophysicists have asserted all of the above?

The Calculators of Calm
The lengths to which the airlines will go to avoid choppy air.

Of Kingfishers and Seagulls
What life was like for the pilots of spotter aircraft during World War II, when battleships and cruisers served as aircraft carriers of sorts, launching the spotters with gunpowder-driven catapults.

ON THE WEB SITE

www.airspacemag.com

Check the Web site for news about *Fighter Pilot: Operation Red Flag* ("Uncommon Force," p. 36). In December, it will open at 12 locations, including the National Air and Space Museum's Steven F. Udvar-Hazy Center.

Our compilation of twin-tail-boom airplanes, "Fork-tailed Devils and Flying Shoes" (p. 64), barely scratches the surface. For the Web site, we've rounded up pictures of more, some we bet you've never seen.

COURTESY MARIO RACHELE

New IMAX® movie star: the F-16.

The best-known twin-tail-boom airplane is the P-38 Lightning. For the less known, visit the Web site.

© PHILIP MAKANNA/GHOSTS

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PAUL GROVER

Basket Case

When David Hempleman-Adams was planning a solo balloon trip across the Atlantic Ocean two years ago, he knew the easiest and safest way to go would be to make the trip in a fully enclosed and technologically advanced gondola. But he decided instead to attempt the flight in a simple wicker basket. "It was just a second-hand basket," says Hempleman-Adams, a 47-year-old from England. "I think I paid $200 for it."

Hempleman-Adams is an accomplished explorer and adventurer—he has been to both poles and has climbed the highest peak on each continent. He also has ballooning experience: He had made one flight from Norway to the North Pole, believed to be the first of its kind.

His eye now on the Atlantic, he made several attempts in 2002 and 2003 but had to abort. With favorable conditions on September 26, 2003, Hempleman-Adams took off from Sussex, New Brunswick, Canada, in a Roziere balloon, which uses both hot air and helium.

As he rose, he was smacked with the reality of life in a balloon at 10,000 feet. The temperature dropped to –22 degrees, and he had only ski clothes and no heating equipment. "It was just bone-crunchingly cold and my teeth kept chattering," Hempleman-Adams says. "It was just a long, deep, black night, but when I saw those first few rays of light in the morning, that blue tinge, psychologically I just felt warmer.

"To try to accomplish what I was doing, there's some danger. If you screw up, you can be in the water. If you look down at the floor, you can see the ocean through the wicker."

Guided by an experienced crew on the ground that tracked his progress and weather conditions, Hempleman-Adams says all he really had to do was try to keep the balloon on course and survive the extreme conditions. His altitude and course needed constant monitoring, so he stayed awake for the entire trip.

While things went relatively smoothly over the western Atlantic, Hempleman-Adams encountered harsh conditions near Ireland, including severe icing and white-out conditions. The weight added by the icing increased the risk of a crash, so he cut away spent helium tanks to compensate and stay at a safer altitude.

Just hours later, Hempleman-Adams touched down in Blackpool, England. His trip had taken 83 hours—about two and a half times the duration of Charles Lindbergh's first solo transatlantic flight in an airplane. Like Lindbergh, the balloonist became a transatlantic trailblazer: He is believed to be the first person to make the trip solo in an open basket.

In recognition of his flight, the National Aeronautic Association awarded Hempleman-Adams the prestigious Harmon Aeronaut Trophy, given for the year's most outstanding international achievement in the art or science of ballooning. (It was his second Harmon; he had earned his first with his Norway-North Pole trip.) "Crossing the Atlantic is one of those iconic flights," Hempleman-Adams says. "It was a great adventure for me."

—Dustin Gouker

LOGBOOK

Nominations

Nominations are being accepted through January 17, 2005, for the Robert J. Collier Trophy. The trophy, commissioned in 1910, is awarded annually for the greatest aeronautic or astronautic achievement in the United States, the value of which has been demonstrated by actual use in the preceding year.

Awards

Former American Airlines CEO Robert Crandall was awarded the 2004 Wright Brothers Trophy for his role in helping to shape the airline industry following government deregulation in the 1970s. Innovations during his tenure, such as frequent flier programs and super-saver fares, are now staples of the industry. He also perfected the hub-and-spoke system now used by most major airlines. Today, Crandall is the chairman of POGO, an air taxi service that plans to use very light jets for on-demand service to and from small airports. The Wright Brothers trophy is presented annually to a living individual for significant public service of enduring value to aviation in the United States. Crandall will be presented the NAA award on December 17, 2004, at a dinner to be hosted by the Aero Club of Washington, D.C.

The 2004 Katherine & Marjorie Stinson Award for Achievement was granted to Ann B. Carl, a World War II test pilot who in October 1944 became the first woman to fly a turbojet aircraft, the YP-59A. Prior to that, she was assigned to the Materiel Command Flight Test Division, where she was the sole female experimental test pilot for military combat aircraft in World War II. Carl received the award at the NAA's annual Fall Awards Banquet on November 8, 2004, in Arlington, Virginia.

Moments & Milestones is produced in association with the National Aeronautic Association. Visit the NAA Web site at www.naa-usa.org *or call (703) 527-0226.*

Inside the GLOBAL HAWK

NORTHROP GRUMMAN'S HIGH-FLYING, ALL-SEEING EYE IN THE SKY

AIR&SPACE Smithsonian

A supplement to the December 2004/January 2005 issue of AIR & SPACE/SMITHSONIAN; © Smithsonian Institution, 2005.
Cutaway Illustration: Randy Crawford/Northrop Grumman.
Sources: Raytheon Defense Systems, Northrop Grumman Integrated Systems, U.S. Air Force.
Design: Ted Lopez/Eason Associates Inc.

INTEGRATED SENSOR SUITE

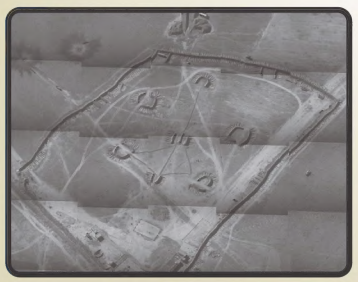
Components of the Global Hawk's principal payload and approximate location of each

Sensor Electronics Unit | Electro-Optical/Infrared Sensor | Transmitter | Receiver/Exciter/Controller | Synthetic Aperture Radar Antenna | Integrated Sensor Processor

HOW IT SEES WHAT IT SEES

- Sensors can see in visual, infrared, and radar electromagnetic spectra
- 10-inch telescope is "eye" for visual and infrared imaging
- Spot-collection mode: 1,900 2-km by 2-km areas per day
- Wide area search mode: >50,000 square miles per day
- Radar: X-band; sensitivity to moving ground targets: minimum 5 mph
- Synthetic aperture radar penetrates cloud, haze, smoke, darkness
- Radar resolution: wide-area mode, 3 feet; spot mode, 1 foot
- Images relayed to ground stations in near real time via satellite link

Synthetic aperture radar view of Naval Air Station Fallon, Nevada.

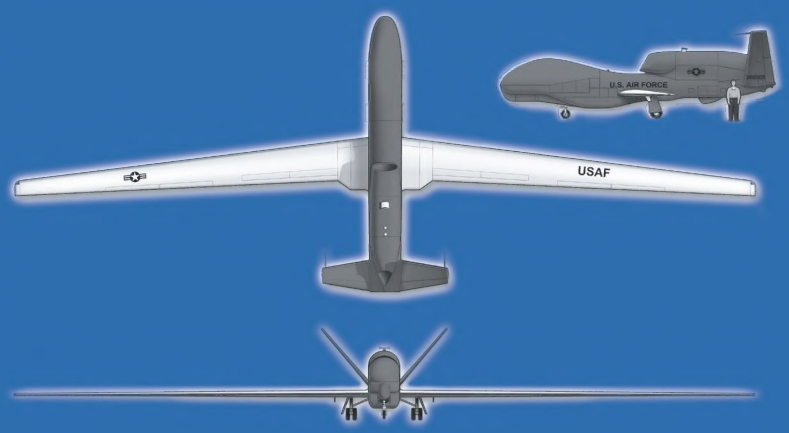


Infrared view of undisclosed overseas location.

Electro-optical view of Naval Air Station China Lake, California.

SPECIFICATIONS, RQ-4A

Gross weight	25,600 pounds
Payload	2,000 pounds
Empty weight	9,200 pounds
Range	15,500 miles (13,500 nautical miles)
Endurance	42 hours
Maximum altitude	>65,000 feet
Mission speed	395 mph (343 knots)
Length	44 feet, 4 inches
Wingspan	116 feet, 2 inches
Height	15 feet, 2 inches
Engine	Rolls-Royce North America AE3007H turbofan; 8,290 pounds thrust at sea level



WHO BUILDS IT

Prime contractor	Northrop Grumman Ryan Aeronautical Center, San Diego, CA
Engine	Rolls-Royce North America, Indianapolis, IN
Sensors, ground systems	Raytheon Defense Systems Falls Church, VA, and El Segundo, CA
Communications	L-3 Com, Salt Lake City, UT
Wing	Vought Aircraft Industries, Dallas, TX

AIR&SPACE Smithsonian PRESENTS

THE NORTHROP GRUMMAN RQ-4A GLOBAL HAWK

The U.S. military's newest spyplane carries an array of sensors—but no pilot.